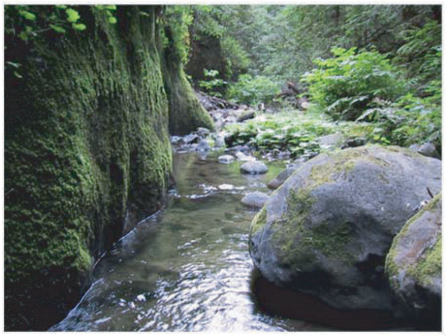
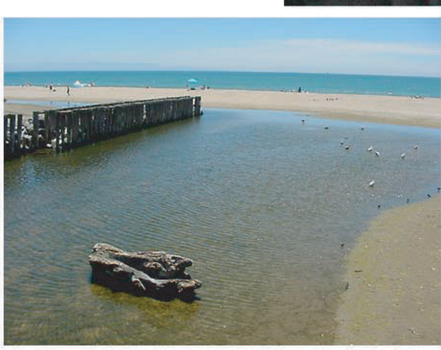
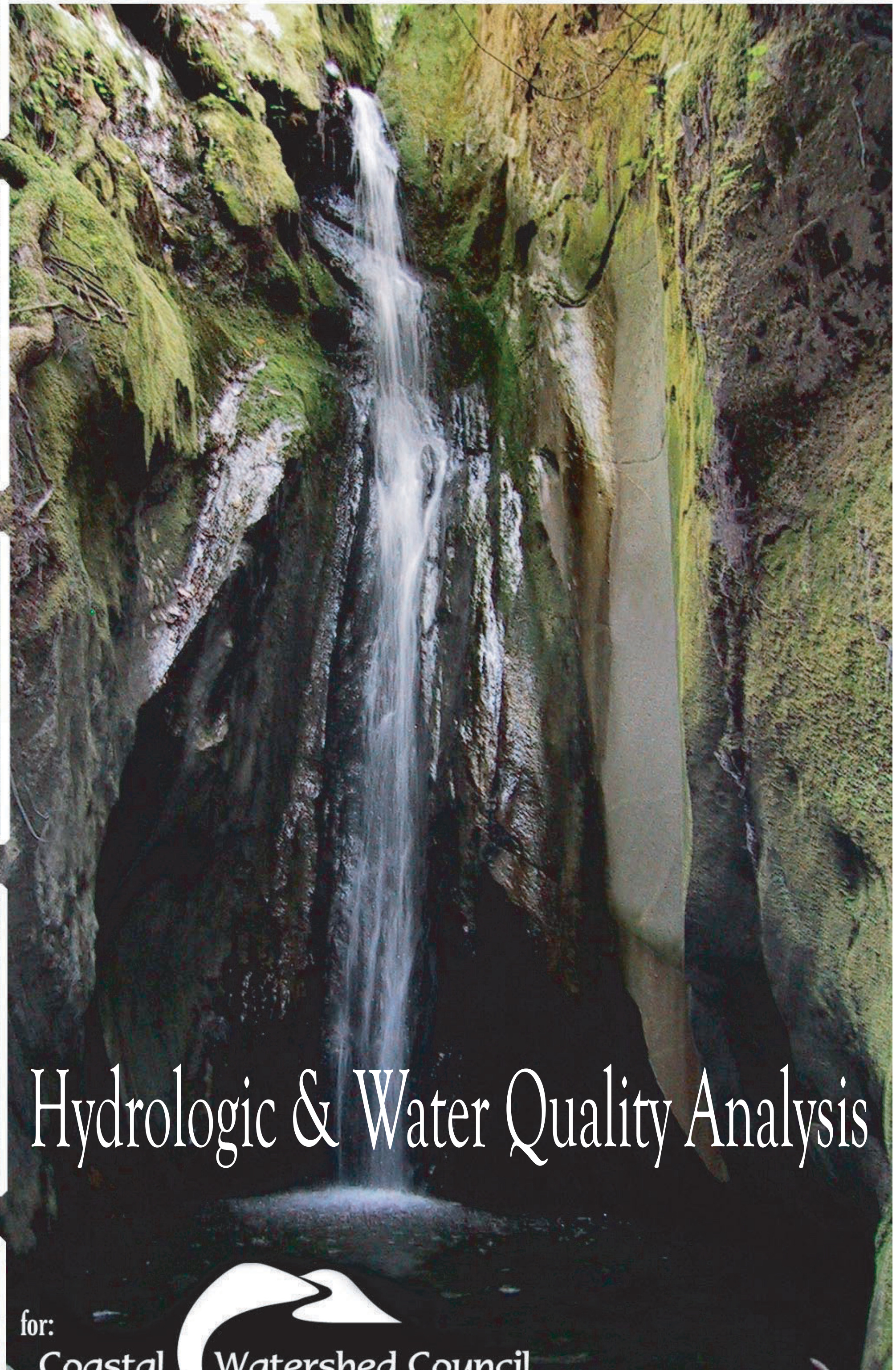
Aptos Creek Watershed

Assessment & Enhancement Plan







Hydrologic & Water Quality Analysis

for: Coastal Watershed Council

by: Swanson Hydrology & Geomorphology
Nicole G. Beck, PhD and Maggie Mathias

May 1, 2003

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1.0 – INTRODUCTION

1.1 – PURPOSE OF STUDY

Swanson Hydrology & Geomorphology (SH&G) was retained by the Coastal Watershed Council (CWC) to conduct a watershed assessment and characterize the hydrologic, geomorphic, vegetation, and fisheries conditions of the Aptos Creek Watershed in Santa Cruz County, California (**Figure 1**). This report summarizes the hydrologic and water quality analysis performed during the 2002 water year and includes the methods of data collection and analysis, the results of the various hydrologic and water quality studies, and future recommendations to improve the hydrologic and water quality conditions for enhancement of anadromous fish in Aptos Creek.

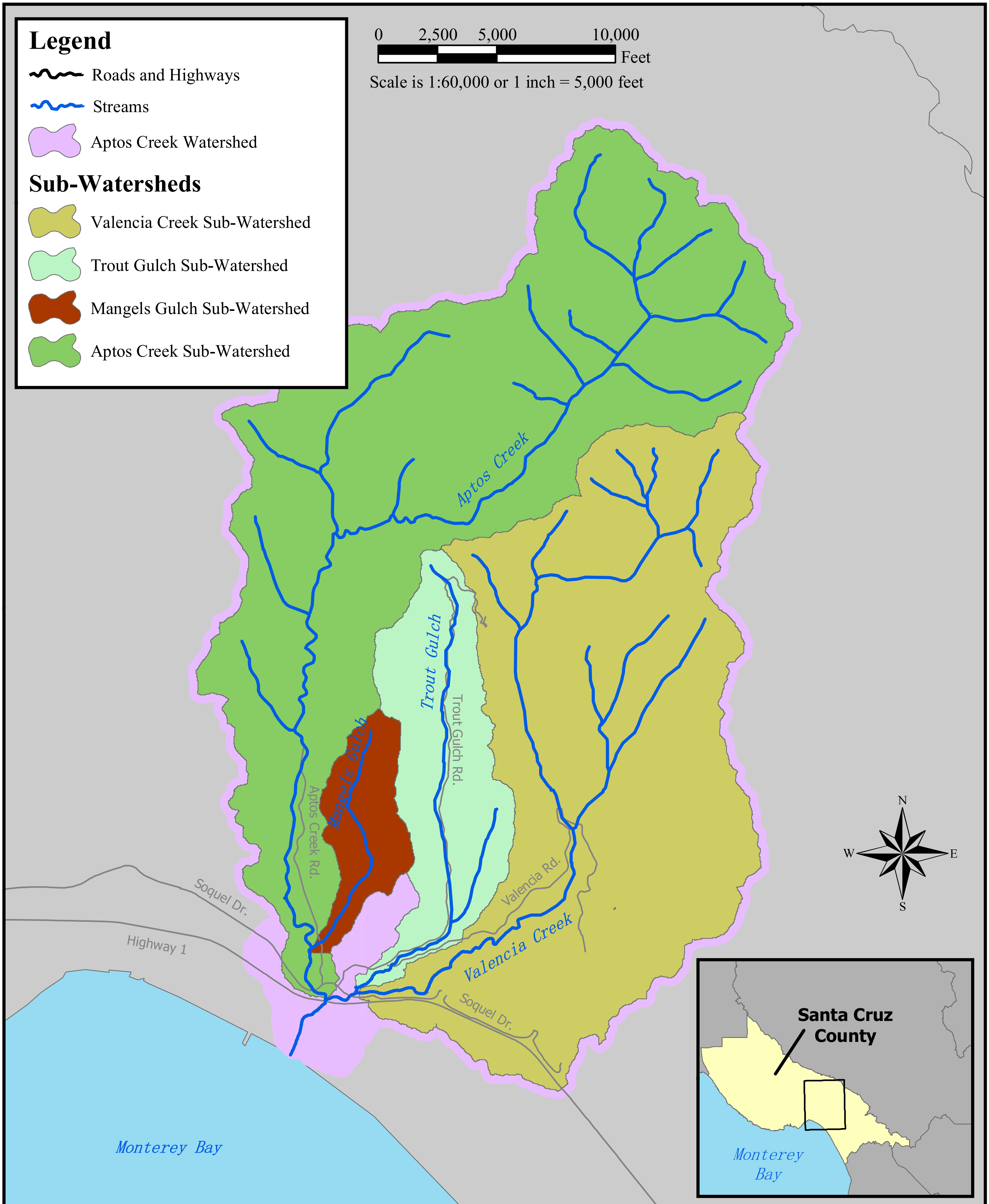
The primary goals and objectives of the hydrologic and water quality analysis were to:

- Evaluate historic stream flow and climatic records to characterize the local hydrology.
- Collect stream flow data to evaluate the spatial and temporal hydrologic variability of the primary streams within the Aptos Creek Watershed.
- Develop a data collection program that could be implemented by CWC stream monitoring volunteers and continued beyond the duration of this project.
- Evaluate the potential impacts of groundwater extractions and surface water diversions on baseflow conditions within the Aptos Creek Watershed.
- Collect and evaluate ancillary water quality parameters from various locations within the lower watershed.
- Collect and evaluate high-resolution water quality data from the Aptos Creek Lagoon.
- Develop recommendations to improve hydrologic and water quality conditions in the watershed that balance the needs of aquatic ecosystems with the water resource needs of humans.

1.2 – BACKGROUND

The Aptos Creek Watershed is located in the temperate climate of the Central California coast, characterized by cool wet winters and dry warm summers. The dry season typically lasts from May to October with stream flow declining through this period. The lowest flows of the season typically occur in August and September until the winter rains return in December. Summer days near the coast can stay fairly cool due to the influence of the coastal marine layer. When winter rains hit the coastline, the amount of precipitation is enhanced by steep terrain, producing orographic uplift and heavy rains, especially in the upper watershed. Average annual rainfall totals range from over 50 in/yr in the headwaters to 22 in/yr at the mouth.

There are two main subwatersheds that make up the Aptos Creek Watershed: Aptos Creek and Valencia Creek (Figure 1). These two subwatersheds are similar in size; Aptos Creek totals 11.2 mi^2 and Valencia Creek totals 9.41 mi^2. Their confluence occurs approximately 0.5 miles upstream of the coastal lagoon. Several other smaller subwatersheds occur within each of these primary subwatersheds, including Bridge and Mangels Gulch in the Aptos Creek subwatershed, and Trout Gulch in the Valencia Creek subwatershed (**Table 1**).



Swanson Hydrology and Geomorphology 115 Limekiln St. Santa Cruz, CA 95060 tel. 831-427-0288 fax. 427-0472	Aptos Creek Watershed Sub-Watershed Delineation	Figure 1

Historically, both the Aptos and Valencia Creek Watersheds were heavily forested with a mixture of redwood, Douglas fir, tanoak, madrone, and oak and extensively logged through the 1920's. Recent land use conditions in these two watersheds have diverged considerably (Table 1). Much of the Aptos Creek subwatershed is protected in the Forest of Nisene Marks, part of the California State Parks system, with the exception of Mangels Gulch and the lower portion of the Aptos Watershed where urban and rural residential land uses dominate. The Valencia Creek subwatershed, including Trout Gulch, is predominately privately owned with much of the lower watershed dominated by urban and rural residential land uses. Rural residential development is increasing in the upper watershed, though much of the land consists of large parcels dominated by orchards and selective logging.

Table 1: Characteristics of the main tributaries of the Aptos Creek Watershed.

Subwatershed	Sub-Shed Area (mi^2)	Main Tributary Length (mi)	Elev. Peak of Sub-Shed (ft)	Area and (%) of Impervious Surfaces[1]	Predominant Land Use
Aptos/ Bridge Creek	11.2	7.2	2624	0.23 mi^2 (2.1%)	Predominantly dense forested in upper watershed with a few residential parcels and open spaces in lower watershed.
Mangels Gulch	0.85	2.0	860	0.04 mi^2 (4.7 %)	Predominately rural residential.
Trout Gulch	2.33	4.0	979	0.12 mi^2 (5.2 %)	Rural residential, forested lands, and orchards.
Valencia Creek	9.41	7.3	1928	0.72 mi^2 (7.7 %)	Dense residential in lower watershed with rural residential, forested lands, and orchards in upper watershed.
Total	24.2	20.5	2624	1.1 mi^2 (4.5 %)	Urbanized in lower portions with channel highly modified through lagoon reach.

1 – Percent impervious was estimated using a set of Santa Cruz County GIS layers depicting roads and parcels. Total road length was summed for each subwatershed area and multiplied by 30, assumed to be an average road width, to generate a total road area. The parcel layer was used to determine the total number of parcels in each subwatershed. Each parcel was assumed to have an impervious surface area of 2,000 sq ft including driveways, roof areas, etc. Both values were converted to square miles and summed to provide an estimate of the total impervious surface area for each subwatershed.

1.2.1 - Hydrology

The hydrology of the Aptos and Valencia Creek watersheds is typical of the conditions found in most small coastal streams of Santa Cruz County. Winter peak flow events can be characterized as flashy and are tied closely to the duration and magnitude of winter rainfall and antecedent soil moisture conditions. At the onset of the rainy season in late Fall, much of the rainfall acts to saturate the soil and fill depression storage on the landscape, with little direct runoff to the stream channels. Once the soil is saturated, additional rainfall directly contributes to runoff and other sources of flow, such as springs and seeps, become active. In an average winter, soil conditions will be saturated through April. Consequently, these months tend to have the highest runoff (**Figure 2**).

Stormflow and winter and summer baseflow conditions are also directly influenced by geologic, soil, and land use conditions present within each of the subwatersheds. Though the geologic conditions are discussed in detail in the Geomorphology and Sediment Source Assessment Technical Memorandum, a brief discussion is warranted in this report to understand observed and measured differences in the hydrology between Aptos and Valencia Creeks.

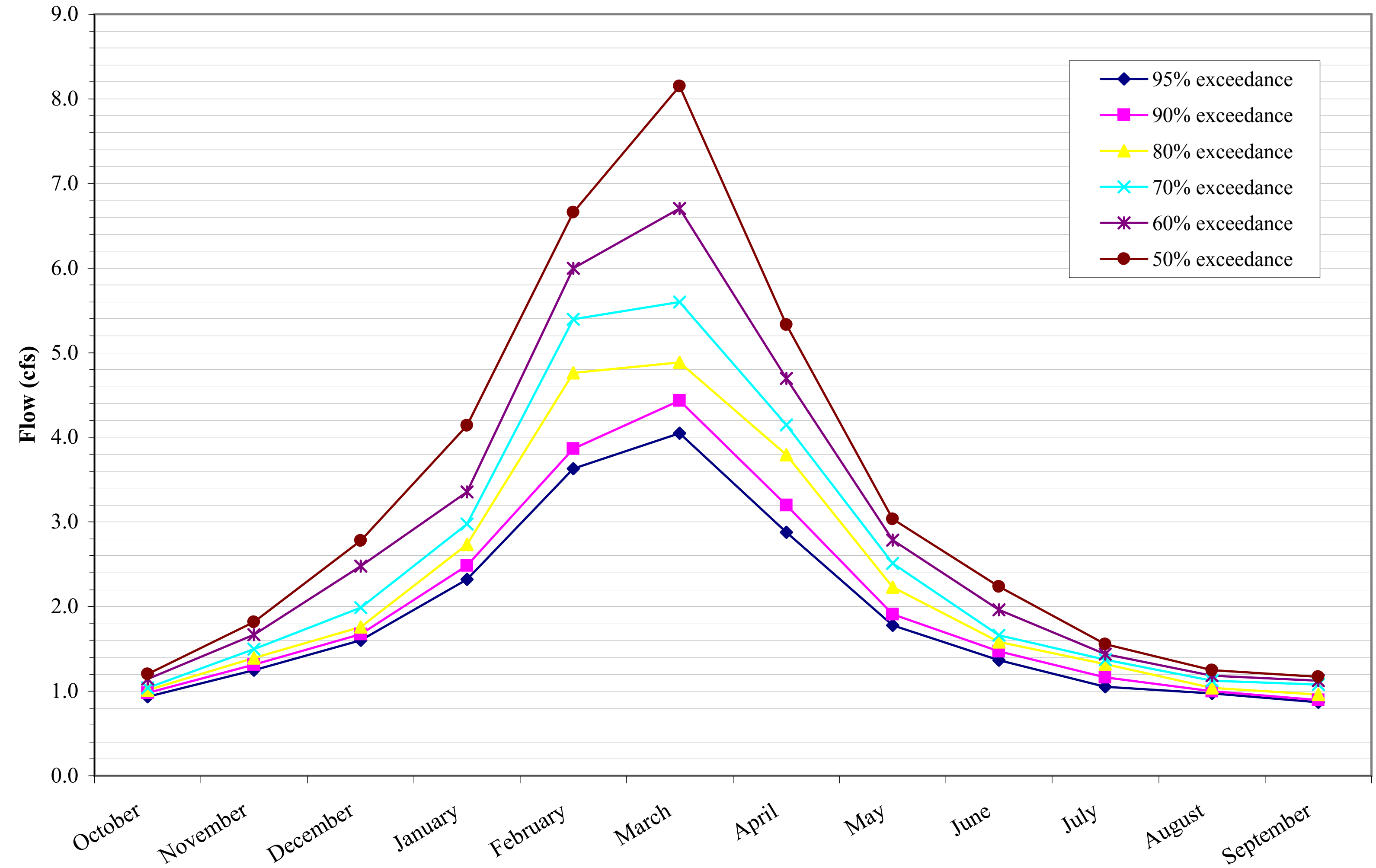


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Figure 2: Monthly exceedence probabilities in an *average* year for USGS gages 11159690, Aptos Creek near Aptos, CA (1971-1985) and 11159700, Aptos Creek at Aptos (1958-1971). Exceedence probabilities are calculated by sorting all available mean daily flow values by month. Exceedence probabilities give information about how often a certain flow value is exceeded.

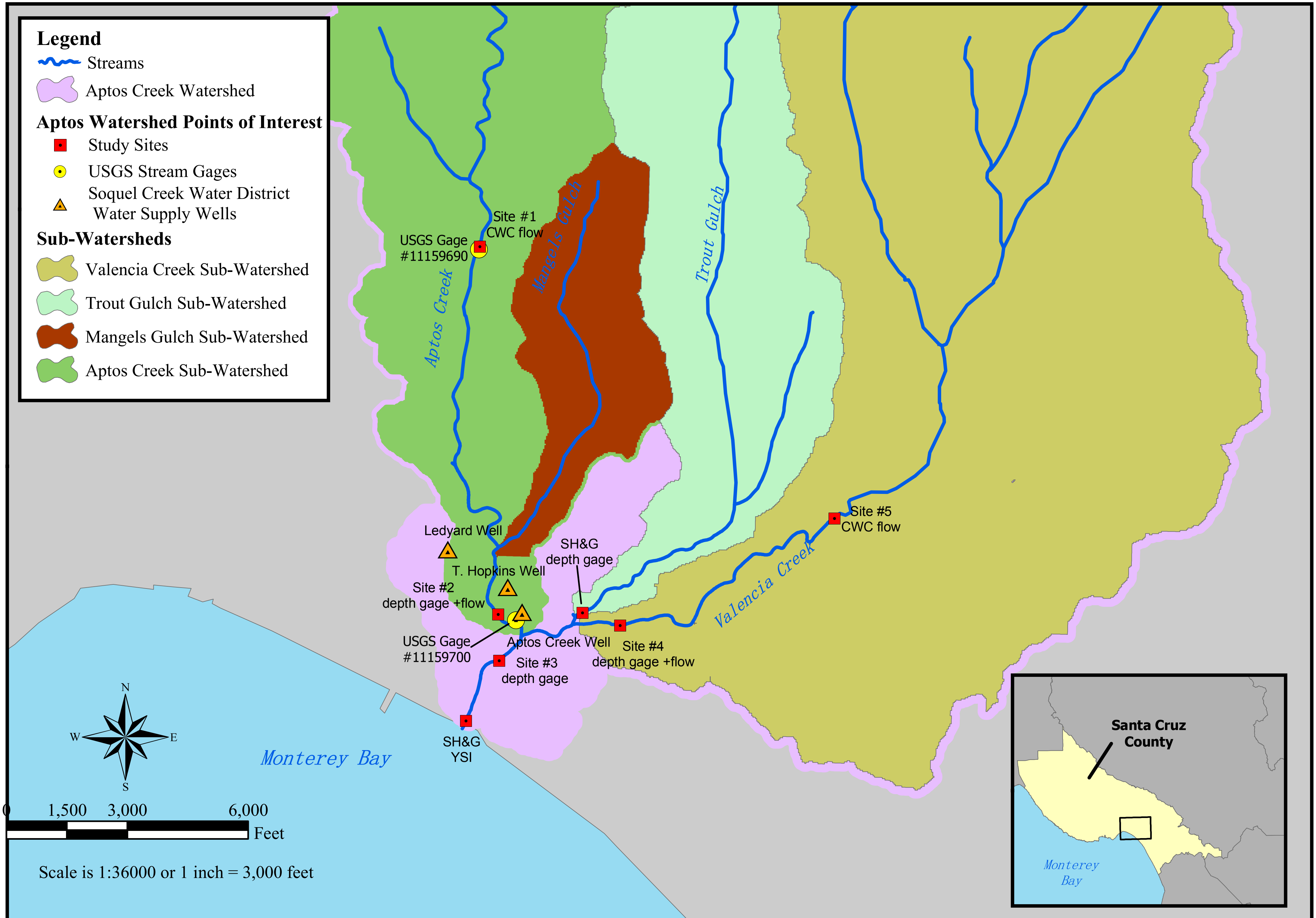
The predominant geologic formation in the Aptos Creek subwatershed is the Purisima (see geology map in Geomorphic Analysis). The Purisima Formation consists of a series of thickly bedded marine deposits dating back to the Pliocene and later Miocene, over 5 million years ago. The formation is predominately siltstone though interbeddings of clay and conglomerates do exist, which are important characteristics for groundwater storage. The Purisima is an important source of groundwater for the Soquel and Central Water Districts. The Purisima also occurs in the upper watershed of Valencia Creek and throughout the Trout Gulch Watershed. Much of the Valencia Creek subwatershed is underlain by unconsolidated Quaternary deposits such as the Aromas Sand. These unconsolidated materials and the soils that are generated from them are likely to be highly permeable. The Aromas Sand is also another source of groundwater for the Soquel and Central Water Districts.

Given the similarly sized drainage areas of Aptos and Valencia Creek and their close proximity to each other, the initial assumption could be that the hydrology is very similar. Significant differences in the geology of each watershed and their markedly different modern land use characteristics preclude us from making this assumption. The Aptos Creek subwatershed also reaches higher elevations with more bedrock exposure in the upper watershed. Given these disparate conditions between the two watersheds, we can generally expect the following characteristics to occur:

1. *Water Yield*: We would expect Aptos Creek to have a higher per unit yield of runoff than Valencia due to the steeper terrain and less pervious geologic formation. Increases in impervious surfaces in the Valencia Creek watershed due to urbanization may reverse this condition during early and late season rainfall events, or during rain events that are short in duration and low intensity.
2. *Peak Flow*: Steeper terrain and less pervious soils in Aptos Creek would suggest higher peak discharge as compared to Valencia. Increased impervious surfaces in Valencia would likely not offset this conditions since soils are likely to be saturated everywhere during a peak runoff event.
3. *Winter and Summer Baseflow*: We would predict slightly higher baseflow conditions in Aptos as compared to Valencia since springs may be more prevalent in the Purisima due to confining clay layers as compared to the Aromas, which is deep and fairly homogeneous. The prevalence of sandy conditions on the bed of Valencia Creek may also result in a significant amount of underflow through the sand deposits, especially in the low flow months.

Very little hydrologic data exists for the Aptos Creek Watershed. What is available only describes the hydrologic conditions on Aptos Creek, upstream of the Valencia Creek confluence. The USGS historically maintained two stream gages on the Aptos Creek, both located upstream of the Valencia Creek confluence (**Figure 3**). USGS gage # 11159700 (Aptos Creek at Aptos, CA) has a contributing area of 12.3 mi^2 and was in operation from 1959 to 1972. USGS gage #11159690 (Aptos Creek near Aptos, CA) has a contributing drainage area of 10.2 mi^2 and was in operation from 1972 to 1985. No other long-term stream flow monitoring stations occur in the rest of watershed, leaving a significant data gap regarding hydrologic conditions in the Valencia Creek subwatershed. Without these long-term data sets, only inferences can be made based on observed conditions in the channel and the uplands.

The peak flow of record in Aptos Creek (3,980 cfs), upstream of the Valencia Creek confluence, occurred on January 4, 1982 (**Table 2**). A much longer data set of peak flow values is available from the neighboring watershed of Soquel Creek (WY 1951-2001). With the exception of the storm of December 1955, the largest flow recorded on Soquel Creek is January 4, 1982. Based on the Soquel Creek records it is reasonable to assume that no flow has exceeded 3,980 cfs on Aptos Creek over the past 40 years.



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Aptos Creek Watershed
Lower Watershed Points of Intersest

Figure 3

Table 2. Peak stream flow measurements of Aptos Creek above the confluence with Valencia Creek. WY 1959-1972 measured at #USGS 11159700 (DA= 12.3 mi^2); WY 1972-1984 (*italics*) measured at #USGS 11159690 (DA= 10.2 mi^2)

Water Year	Date	Peak Stream flow (cfs)
1959	Jan. 9, 1959	299
1960	Feb. 8, 1960	302
1961	Nov. 26, 1960	24
1962	Feb. 14, 1962	560
1963	Jan. 31, 1963	2,110
1964	Jan. 21, 1964	262
1965	Dec. 22, 1964	968
1966	Dec. 25, 1965	46
1967	Mar. 16, 1967	1,310
1968	Jan. 30, 1968	846
1969	Jan. 18, 1969	966
1970	Jan. 16, 1970	1,130
1971	Nov. 29, 1970	400
1972	Feb. 5, 1972	34
1972	*Feb. 5, 1972*	*30*
1973	*Jan. 16, 1973*	*1,200*
1974	*Mar. 28, 1974*	*420*
1975	*Feb. 13, 1975*	*425*
1976	*Feb. 29, 1976*	*27*
1977	*Dec. 30, 1976*	*13*
1978	*Jan. 16, 1978*	*1,090*
1979	*Feb. 13, 1979*	*192*
1980	*Jan. 13, 1980*	*1,000*
1981	*Mar. 21, 1981*	*328*
1982	*Jan. 4, 1982*	*3,980*
1983	*Jan. 24, 1983*	*1,030*

A flood frequency analysis, performed on the combined 25-year annual series peak flow record from 1959-1984, suggests that the flow that occurred on January 2, 1982 was slightly greater than a 20-year event (**Table 3** and **Figure 4**). While the 28 year record is the compilation of two different gages, we assume that the drainage area of 2.1 mi^2 of low lying areas during peak runoff events will have a minor impact on the peak stream discharge values.

Table 3: Flood recurrence intervals for Aptos Creek above the Valencia Creek confluence calculated using the combined peak flow data for USGS gages #11159690 and 11159700.

Recurrence Interval (years)	Flow (cfs)
500	13,800
200	10,200
100	7,870
50	5,850
20	3,660
10	2,350
5	1,330
2	402
1	7.0

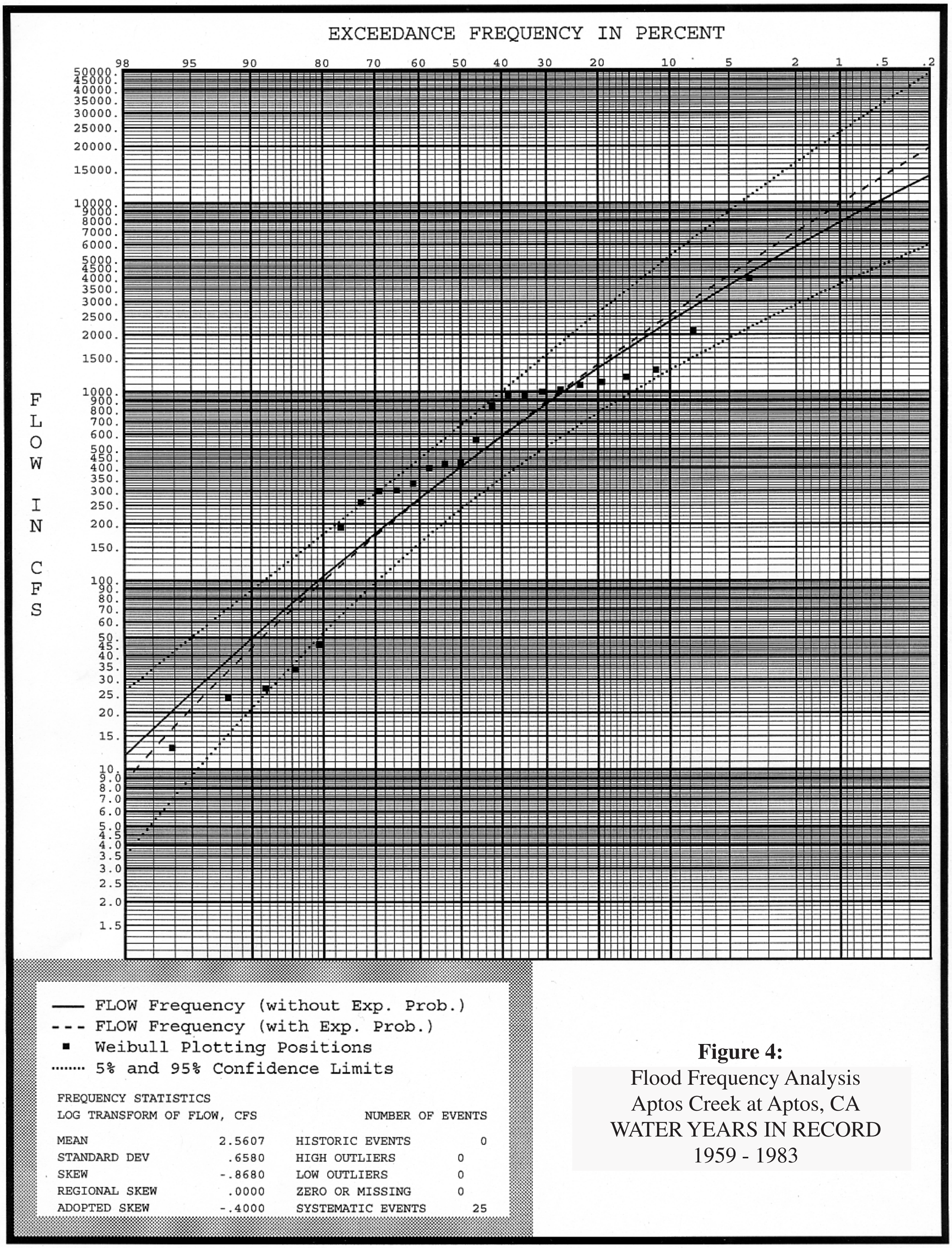


Figure 4:
Flood Frequency Analysis
Aptos Creek at Aptos, CA
WATER YEARS IN RECORD
1959 - 1983

Source: Output by HEC-FFA for peak flow data from USGS gages 11159690 and 11159700 period of record, 1959-1983.

1.2.2 - Water Quality

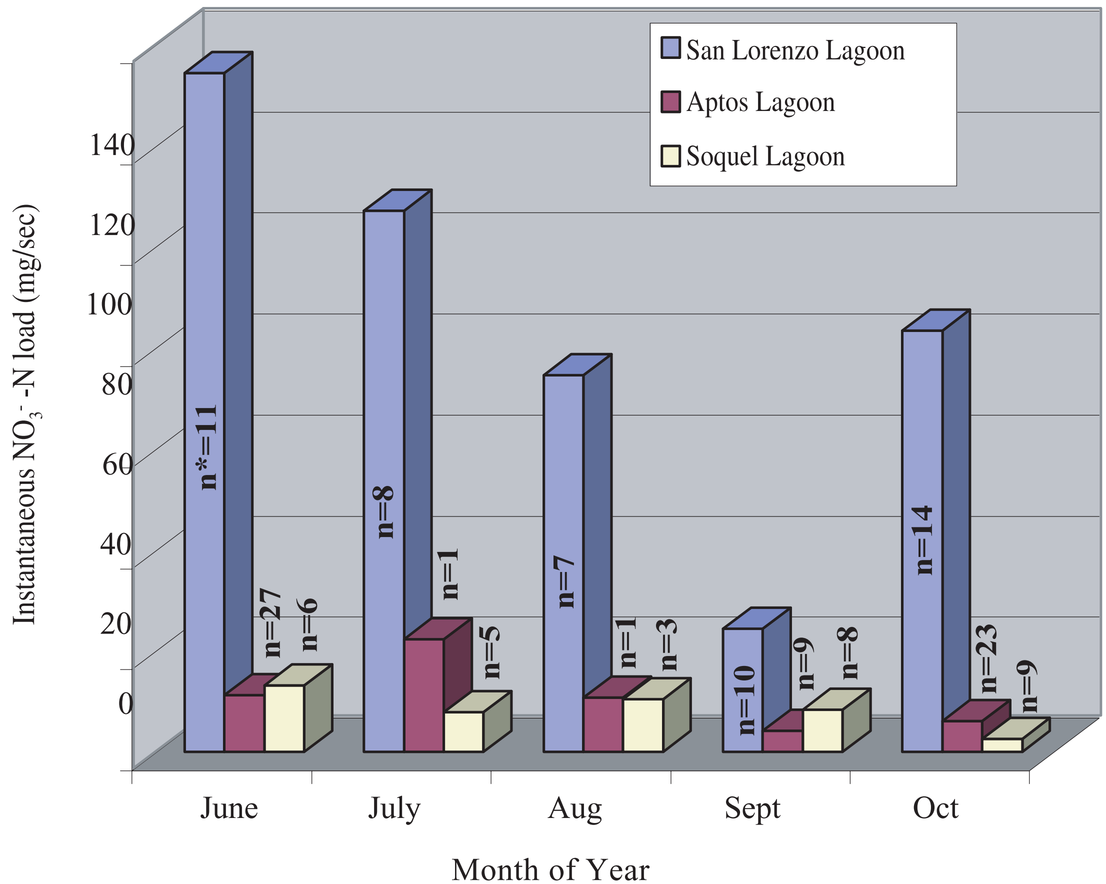
The focus of most of the previous water quality investigations within the Aptos Creek Watershed has been the potential impact of stream water quality on the coastal lagoon and near-shore waters and beaches. Much of the investigation relates to the impacts of water quality on human health in response to the high recreational use of the coastal areas by bathers, swimmers, surfers, and the importance of the tourism industry.

Perennial inflows from Aptos Creek and Valencia Creek transport water, nutrients, and various other dissolved and suspended constituents to the lagoon and coastal waters of Monterey Bay. Some of these constituents may have the potential to directly impact human health by degrading the water quality while others may affect the ability of the ecosystem to absorb these constituents, ultimately having a detrimental impact on the flora and fauna supported by the stream and the lagoon system. The common, easily measurable constituents that may result in degraded water quality include nitrogen, phosphorus, fecal coliform bacteria, and enterococcus bacteria. These constituents are all naturally occurring but if found at high concentrations or in excessive amounts can cause degraded water quality conditions. The sources of these potentially detrimental constituents include septic systems, animal waste, leaking sewer lines, discarded landscape materials, and agricultural runoff.

The Santa Cruz County Environmental Health Department has collected monthly water samples in coastal lagoons and streams throughout the County. **Figure 5** is a comparison of the average monthly N loading rates to four local lagoon systems, Aptos Lagoon, Soquel Lagoon, San Lorenzo Lagoon and Pescadero Marsh. The data suggest relatively low levels of N delivery to Aptos Lagoon relative to the values in San Lorenzo. The majority of the nutrient data collected by local agencies has been limited to biologically available N (nitrate). Nitrate values in Aptos Creek have been fairly low for human health standards, but high enough to potentially induce excessive algae growth, a process referred to as eutrophication. The lack of simultaneous biologically available P data for the tributaries limits our interpretation of the degree to which eutrophication in the lagoon is caused by inflowing waters.

The Santa Cruz chapter of the Surfrider Foundation monitors the fecal coliform and enterococcus levels at the mouth of Aptos Creek and at various locations within the watershed once a week. Consistently the levels in Aptos are found to be elevated relative to the other local coastal monitoring stations. The enterococcus bacteria are a subgroup of the fecal streptococci and studies in marine and freshwater indicate that enterococci are the most efficient bacterial indicator of water quality. Enterococcus is a bacterium found in the human intestine and therefore is a good indicator of human waste, i.e. septic system and sewer system pollution. Fecal coliform is a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are released into the environment through human and animal feces. The presence of fecal pollution may come from storm water runoff, pets and wildlife, and human sewage. The source correlation of nutrient and fecal coliform pollution suggest that observed elevated levels of fecal coliform would correspond with elevated nutrient levels as well. The occurrence of high fecal coliform, enterococcus bacteria and nutrient concentrations in the Aptos Lagoon, especially during storm runoff events, further suggests that coliform levels could be used as an indication of nutrient-enrichment.

Table 4 is a representative example of the local water quality results published by Surfrider. This particular table presents data collected following a significant rainstorm along the Central California Coast in early November 2002. This data can represent a "worst-case" scenario since over 4 inches of rain fell during the first-flush storm that mobilized pollutants both on the surface and in the subsurface that had been accumulating for over 7 months, since the previous winter. Two facts can be inferred from Table 4. First, the bacteria and coliform levels detected at the mouth of Aptos Creek were significantly higher than the other sites. Secondly, there appears to be evidence that the majority of the coliform levels are originating in the Valencia Creek subwatershed. The relative local water quality trends throughout the year are similar to those presented in Table 4, where the mouth of Aptos Creek is continuously a 'hot spot' of poor water quality.



*n equals the number of samples used to calculate average.

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Figure 5: Average monthly nitrate loading to San Lorenzo, Aptos, and Soquel Lagoons: Comparison of three local lagoons during months when mouth closure occurs. Observe the significantly greater amount of NO_3^- loading into the San Lorenzo Lagoon, relative to Soquel. Estimates were determined from the average monthly nitrate concentrations measured by Santa Cruz County at the station in the watershed nearest to the lagoon. Average daily stream flows per month were generated from the USGS gage station closest to the lagoon in each watershed.

Table 4: Santa Cruz Chapter Surfrider Results

Samples Taken on 11/13/2002 (http://www.surfrider.org/scjump.htm)

COASTAL LOCATIONS	fecal coliform*	enter**	rating
Cowell's @ Stairs	60	20	
Cowell's Beach	20	10	
Cowell's @ Outfall	310	740	
Rio Del Mar Beach	180	290	
Aptos Creek @ mouth	**490**	**2000+**	
La Selva Beach	**10**	**860**	
Manresa	10	50	
Sand Dollar	<10	40	

CREEKS	fecal coliform*	enter**	rating
San Lorenzo river @ H. school	90	100	
Aptos Creek @ steel bridge	50	<10	
Nicene Marks Picnic Area	30	50	
Aptos County Park (Aptos Creek Trib)	90	20	
Upper Valencia Creek	**250**	**-**	
Trout Gulch @ Valencia Confluence	**2000+**	**350**	
Storm Drain@ Spreckles rd	**390**	**50**	
Spreckles Bridge	**280**	**20**	
Rivermouth@Aptos Creek	**2000+**	**2000+**	

*** number of fecal coliform bacteria per 100ml**

State standards specify levels of fecal coliform bacteria in swimming areas should not exceed 200 per 100ml.

****number of Enterococcus bacteria per 100mL.**

State Standards specify that Enterococus levels should not exceed 104 per 100mL in swimming areas

2.0 – METHODS

2.1 - HYDROLOGY

2.1.1 – USGS Gage Extension

The stream flow records for the two USGS stream gages on Aptos Creek overlap for the 1972 water year. The close proximity and relatively similar drainage areas of the two gages allows for the creation of a statistical relationship between the two (**Figure 6**) and the extrapolation of the data collected at the downstream gage (#11159700) to extend the total record to over 25 years based on the upstream gage data (#11159690). Low precipitation and stream flow conditions during WY 1972 puts a limitation on the accuracy of the extrapolation at higher stream flows, though we feel the approach provides meaningful results. The remainder of the historic stream flow analysis presented in this report is based on the observed stream flow at the USGS gage # 11159700 from WY 1959-1972 and the extrapolated stream flow at this site from 1973-1985 based on the observed flows at USGS gage # 11159690 and the statistical correlation between the two sites.

While there has not been an active USGS stream flow gage on Aptos Creek since 1985, the neighboring Soquel Creek has had an active USGS stream gage from 1951 to the present (USGS gage #11160000). Using the USGS stream gage data collected simultaneously from Aptos Creek and the neighboring Soquel Creek (WY 1958-1985) an empirical relationship was created between the two gages (**Figure 7**). Using the correlation of these stream flow records, the 2002 water year hydrograph for Aptos Creek upstream of the Valencia Creek confluence was extrapolated from the Soquel Creek data.

2.1.2 – Exceedance Probability Calculations

To understand past flow conditions a standard hydrologic data analysis technique was used to generate exceedance probability values using the average daily stream flow values measured in Aptos Creek from WY 1959-1985. The data were generated for four climatic conditions that denote whether the current flow measurement is typical of a drought, dry, average, or wet condition. A wet condition is defined as average daily flow values that are greater than the 75th percentile. An average flow condition ranges from the 75th to the 25th percentile, a dry condition from the 25th to the 10th percentile and a drought condition is the values occurring below the 10th percentile.

Once the data is sorted by month and climatic condition, the data within each category was analyzed to determine the exceedance probability using standard statistical techniques (Dunne and Leopold, 1978). Given the consistent pattern of wet winters and dry summers that characterizes our Mediterranean climate, this data is valuable when assessing fish passage or the potential impacts of stream flow diversions. It also has dry season predictive capabilities given a particular baseflow value at the end of the high flow season. When balancing water diversions with the need to maintain flow for salmonid rearing, these data can be powerful tools for water resource managers. The lack of long-term hydrologic data for the Valencia Creek subwatershed precludes us from using this method to describe stream flow conditions.

2.1.3 – Stream Flow Gaging

Given the lack of information regarding stream flow conditions within the Valencia Creek watershed and on Aptos Creek below the confluence of Aptos and Valencia, efforts were made to establish

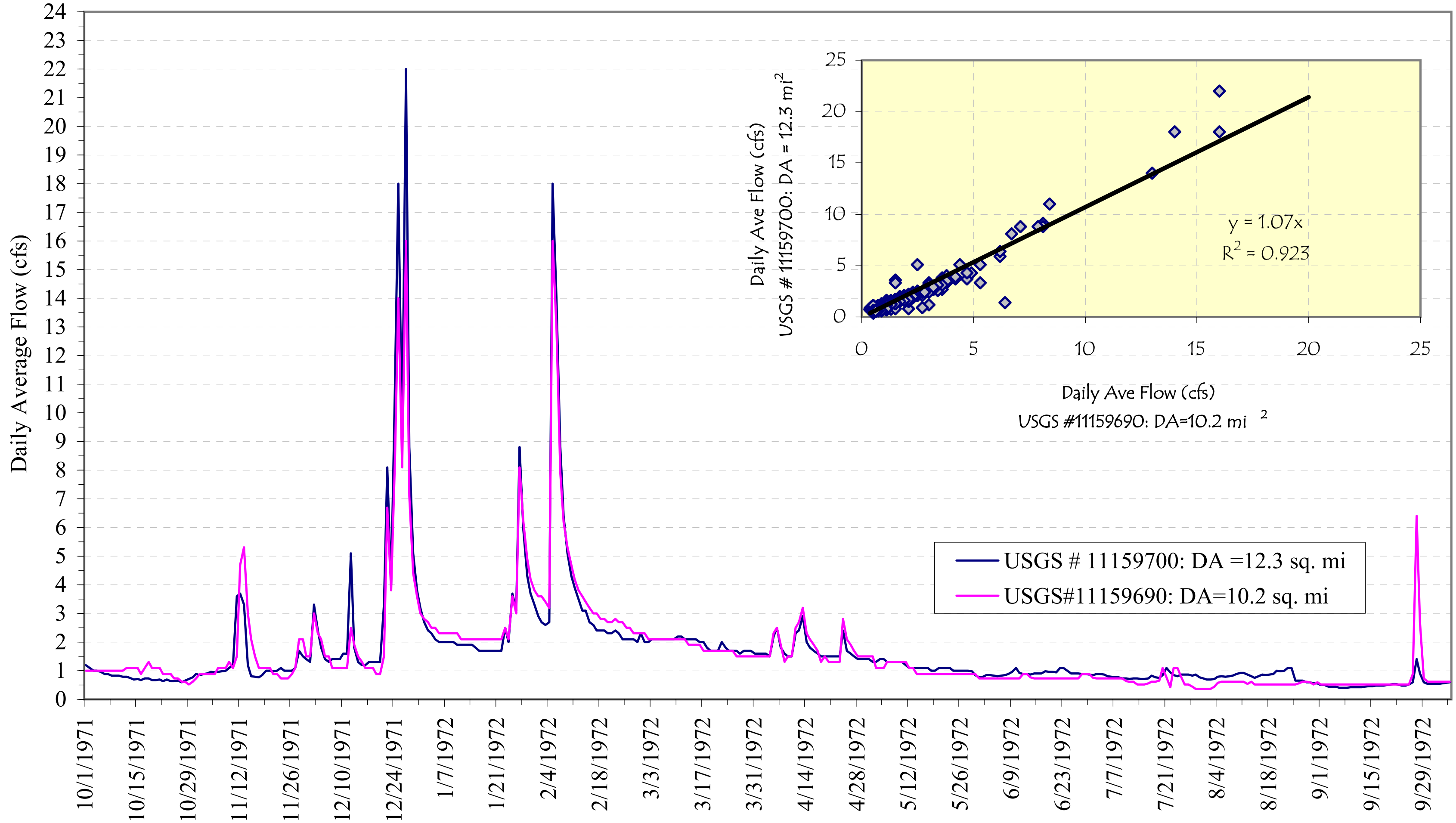

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Figure 6: Hydrograph for USGS gages #11159690 and #11159700 for WY 1972, the period of overlapping data collection at both sites. Inset illustrates the statistical relationship of flows for the two gages.

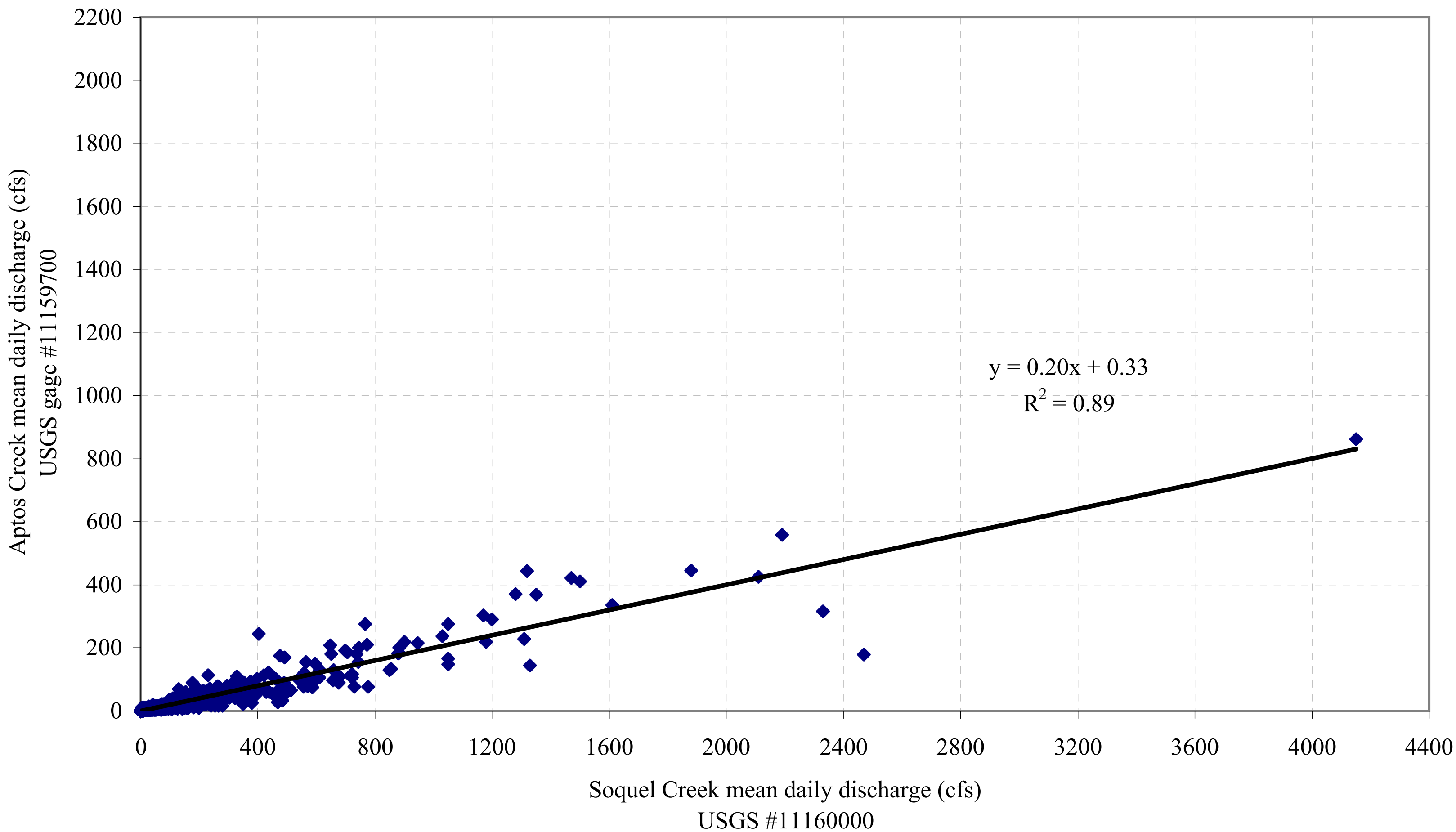

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Figure 7: Empirical relationship between USGS gage #11160000, Soquel Creek at Soquel, and #11159700, Aptos Creek at Aptos, based on the concurrent period of record, 1959 to 1972.

temporary stream flow gages. This involved establishment of continuous water level recording equipment at a location in the field that has a stable cross-section and where discharge is sensitive to changes in flow depth and the subsequent development of a rating curve via in-field discharge measurements at a range of flow depth and flow conditions. The in-field data collection efforts for the hydrologic analysis were a collaborative effort between SH&G and CWC, with a large portion of the discharge measurements collected by the CWC Watershed Volunteers.

Four Global Water WL-14 pressure transducers (**Figure 8A**) were installed within the Aptos Creek Watershed (Figure 2) in the fall of 2001 to provide continuous (30-minute interval) water depth data for the three main tributaries (Aptos Creek at Aptos County Park, Valencia Creek at Valencia School, and Trout Gulch) and the mainstem (at Spreckels Drive) of the watershed. In-stream discharge measurements were conducted by SH&G, CWC personnel or CWC volunteers and followed standard USGS measurement techniques (USGS Water-Supply Paper 2175 – Volume 1, 1982) including the velocity-area method for calculating total stream flow and the sixth-tenths method for determining velocity. Peak discharge events were not measured due to the lack of training for volunteers to obtain measurements using bridge-based flow monitoring equipment and the weekend availability of most of the volunteers.

The CWC volunteers utilized a digital current meter and SH&G staff employed a USGS Type Pygmy or Price AA meter, with calibration conducted to ensure consistent flow measurements between the units. SH&G and CWC performed equipment calibration at the beginning of each monitoring period. A minimum of 10 velocity and depth measurements were taken at each cross-section to ensure that each width measurement did not represent greater than 10% of the total flow. Flow values were computed in the field to ensure quality control of the measurement and to determine if new measurements were needed to improve accuracy. Staff plates installed at each of the sites were used to assess the quality and accuracy of the information obtained from the water level recorders.

Typically, discharge data, water depths collected from the pressure transducers, and staff plate measurements would be correlated to produce a rating curve for each site that relates water depth to discharge. The rating curve would then be used to estimate a hydrograph for the monitoring period. Unfortunately, the data collected at all monitoring sites, except for the Spreckels gage, produced unreliable data due to a combination of equipment failure and an unstable bed cross-section. The instability of the cross-section proved to be the most problematic because a solid, statistically valid relationship between the instantaneous discharge measurements and the water depths, as measured by the gage equipment, could not be established. The dominance of sand on the bed of the channel resulted in scour during high discharge events and aggradation during low flow conditions. Additionally, the pressure transducer was often buried following peak flow events. Bed conditions at the Spreckels site were more stable due to the presence of a concrete grade control structure downstream of the gage, which limited scour and aggradation, though the instrument was periodically inundated with sand due to backwater effects created by the installation hardware.

2.1.4 – Synoptic Flow Measurements

The simple comparison of measured surface water discharge at two different locations within a specific stream reach can provide information to determine if the stream is gaining or losing surface water. A gaining stream will display an increase in discharge downstream as a result of an elevated groundwater table that is contributing to the surface water flow observed in the stream. Any additional surface water inputs between the upstream and downstream stations must be considered when an increase in discharge downstream is observed. A losing stream is the opposite, where discharge observed downstream is less than that at the upstream monitoring station, suggesting water loss (i.e. infiltration, diversion, extraction) from the stream channel. In the Aptos and Valencia Creek

Figure 8A: Global Water WL-14 depth gage and housing located on mainstem Aptos Creek upstream of Spreckles Drive. Data logger is housed in an electrical box affixed to tree, yellow cable runs down tree to the water through black PVC. Sensor is located at bottom of water column, secured to PVC by cable ties. The white PVC in the foreground is the staff plate, used to record depth concurrent with data downloads.

Figure 8B: YSI 600XLM water quality instrument used to collect salinity, water temperature, water depth, dissolved oxygen, conductivity, and pH on 30-minute time intervals. This instrument was installed in the Aptos Lagoon from August 20 to October 21, 2001.

watersheds other factors may contribute to the appearance of a reach being gaining or losing. One potentially confounding factor is the occurrence of grade breaks, which can either force water to the surface due to bedrock outcropping or cause water to flow subsurface in the case of a wide, flat alluvial area. Another confounding factor could be the predominance of a sandy bed, especially in Valencia, Trout, and lower Aptos, where much of the water may flow subsurface through the aggraded sandy material. Only observations were made with regard to the extent to which these confounding factors influenced the results of the synoptic flow results.

The locations of each of the monitoring stations are indicated on Figure 2. The Valencia Creek seepage experiment consisted of discharge measurements conducted within the stream adjacent to Aptos Polo Grounds for the upstream site and at Valencia Elementary School located approximately 6,500 ft downstream. The Aptos Creek Tributary upstream station was located at the steel bridge crossing within Nisene Marks State Park, approximately 9000 ft upstream of the Aptos County Park monitoring station. Between the two Aptos Creek monitoring stations is the confluence of Mangels Gulch, which does contain surface water flow during storm runoff events, but is dry for much of the year. Regardless, when comparing the stream flow measurements within the Aptos Creek Tributary one must keep the potential contribution of water from Mangels Gulch in mind. All discharge measurements used for the seepage results were conducted within a couple of hours of one another. Flows of less than 1 cfs were not included in this study due to the potential for the observed difference being the result of instrument error, rather than actual flow losses or gains.

2.2 - WATER QUALITY

2.2.1 – Multi-parameter Monitoring in Lagoon

The brackish environment and abundant food sources make lagoons and estuaries the most productive systems per unit area on the Earth's surface. The natural seasonal transition of Central California coastal lagoons is from a tidally influenced river mouth in the winter months to an inundated brackish/freshwater system in the summer when a sandbar forms at the mouth. While the natural physical closure of the lagoon continues today, urban development around Aptos Lagoon has severely constricted the area to a width of approximately 70 feet between two vertical concrete levees that extend from the high water line of the ocean upstream approximately 300 ft. Oceanward of a pedestrian bridge, the channel meanders along the Rio Del Mar Beach prior to discharging into the Monterey Bay. When a sandbar forms at the mouth of Aptos Creek, the lagoon habitat is simply brackish water poised atop beach sand exposed to the sunlight, devoid of any vegetation and providing minimal aquatic habitat (**Figures 9A&B**). The intense exposure to sunlight causes dangerously high water temperatures for aquatic species. In addition to the compromised physical habitat, the cultural eutrophication of our local streams and waterways has a deleterious impact on the water quality of many of the Central California coastal lagoons. Since coastal lagoons provide important rearing habitat for steelhead and coho salmon juveniles, impacts to the lagoon may also have a significant impact on these populations.

During summer closure, the physical and chemical system goes through a dramatic shift as circulation is decreased, resulting in increased water temperatures, elevated biological activity (photosynthesis and respiration) and exacerbated chemical cycling. In order to monitor the transformation of the physical, chemical and biological components of the lagoon during the summer months, SH&G installed a high-resolution ancillary water quality data logger (YSI 600XLM) (**Figure 8B**) 100 ft upstream of the pedestrian bridge on August 21, 2001 (**Figure 9C**). The data logger recorded water temperature, salinity, depth, pH, and dissolved oxygen at 30-min intervals, 24-hours per day in the bottom water from August 20-October 2, 2001. On October 2nd the unit was relocated to the middle

Figures 9 A&B: Aptos Lagoon during summer closure. Photo taken from high bluff on the north bank of lagoon. Photo A looks to the south, B to the north.

Figure 9 C: YSI 600XLM unit housing located in Aptos Lagoon. YSI is suspended within white PVC, collecting data at either the bottom or middle of the water column. Housing is located approximately 100 feet upstream of pedestrian bridge visible in Photo A.

of the water column and subsequently removed from the lagoon on October 21, 2001. This data provides a time series of both diel (daily) and seasonal variations in the surface and bottom waters and is particularly valuable to monitor the resultant biogeochemical processes following the closure of the lagoon and the transformation of the water column during decreased circulation.

2.2.2 – Vertical Water Quality Profiles

In addition to the multi-parameter water quality monitoring, SH&G conducted high-resolution vertical profiles in the Aptos Lagoon at two locations on October 2, 2001 from aboard a canoe. Ancillary water chemistry parameters (DO, water temperature, salinity, pH, conductivity and depth) were collected with a hand held YSI-85 multi-parameter probe at a number of depth intervals by securing the YSI probe to a PVC pipe marked with depth increments. Vertical profiles collected with the hand-held DO unit were used to verify the data collected by the YSI, increase the spatial resolution of the data, and provide a picture of the vertical distribution of the water quality conditions throughout the water column.

3.0 – RESULTS AND DISCUSSION

3.1 – HYDROLOGY

The quantity of water and the timing and duration of peak discharge events play an important role in the survival and reproductive cycles of steelhead and coho salmon. Adult steelhead and coho migration to spawning areas is directly tied to the onset of rains and increased stream flow in November when enough flow is present to breach seasonally closed lagoon mouths. **Figure 10** is a histogram of the relative average stream flow per month on Aptos Creek, upstream of the confluence with Valencia, and illustrates that storms and elevated stream flow predominantly occurs from December through April. In most years, the rainy season begins in October, but the soil moisture demand of the surrounding areas is not met until a significant amount of precipitation has occurred. Once the ground is saturated, a greater percentage of the precipitation is converted to stream flow during storm runoff and the continual contribution of groundwater and subsurface flow to the surface channel increases the winter baseflows. The precipitation is typically much lower during April, but the stream flows remain elevated as groundwater and subsurface flow continues to contribute water to the streams. By May, the water levels in the streams are typically low and relatively unresponsive to small spring thundershowers.

Adults will also tend to migrate at the receding end of a high flow event in order to migrate past potential barriers and allow for concealment due to the increase in turbidity. Additionally, higher winter flows can clean spawning gravels that have accumulated debris and fine sediment during the previous summer months and redistribute woody material, allowing for the formation of deep pools. Following winter rains, stream flow declines during the dry season and is often the primary limiting factor for juvenile rearing. The amount of stream flow is often directly related to the quantity and quality of the habitat. The amount of stream flow in the spring and summer months can directly influence macroinvertebrate populations, a primary food source for juvenile salmonids.

Along with the location of barriers, the distribution of surface water during the summer months will be the primary factor in determining the range of steelhead and coho within a particular system. In the Aptos Creek Watershed, perennial, or year-round flow occurs along Aptos Creek, Bridge Creek, and most of Valencia Creek. Trout and Mangels Gulch have sections of perennial flow though much of the channel is dry during the summer months. Historic conditions in these tributaries is difficult to determine due to the confounding effects of sedimentation, which may cause flows to go subsurface, and septic systems, which may be providing a source of summer stream flow that would not have ordinarily been present.

Table 5 summarizes the monthly exceedance probabilities for mean daily flow values collected by the USGS on Aptos Creek, upstream of the confluence with Valencia. Exceedance probabilities in graphical format are presented in **Appendix A**. The immediate insight gained from Table 5 is that during the entire period of record stretching from 1959 to 1985, Aptos Creek did not appear to dry up, though it was extremely close. Additionally, the difference in summer baseflow conditions in a drought year as compared to an average year is fairly considerable. The absolute numbers are not necessarily that revealing, but in most cases, summer flow conditions in an average year are twice what they are in drought years. During the winter months, the differences are even more considerable. According to the data, winter flow conditions during a drought year do not exceed 2 cfs. Such low flow conditions year-round may make it difficult for adult fish to reach preferred spawning areas with significant impacts to the juvenile population.

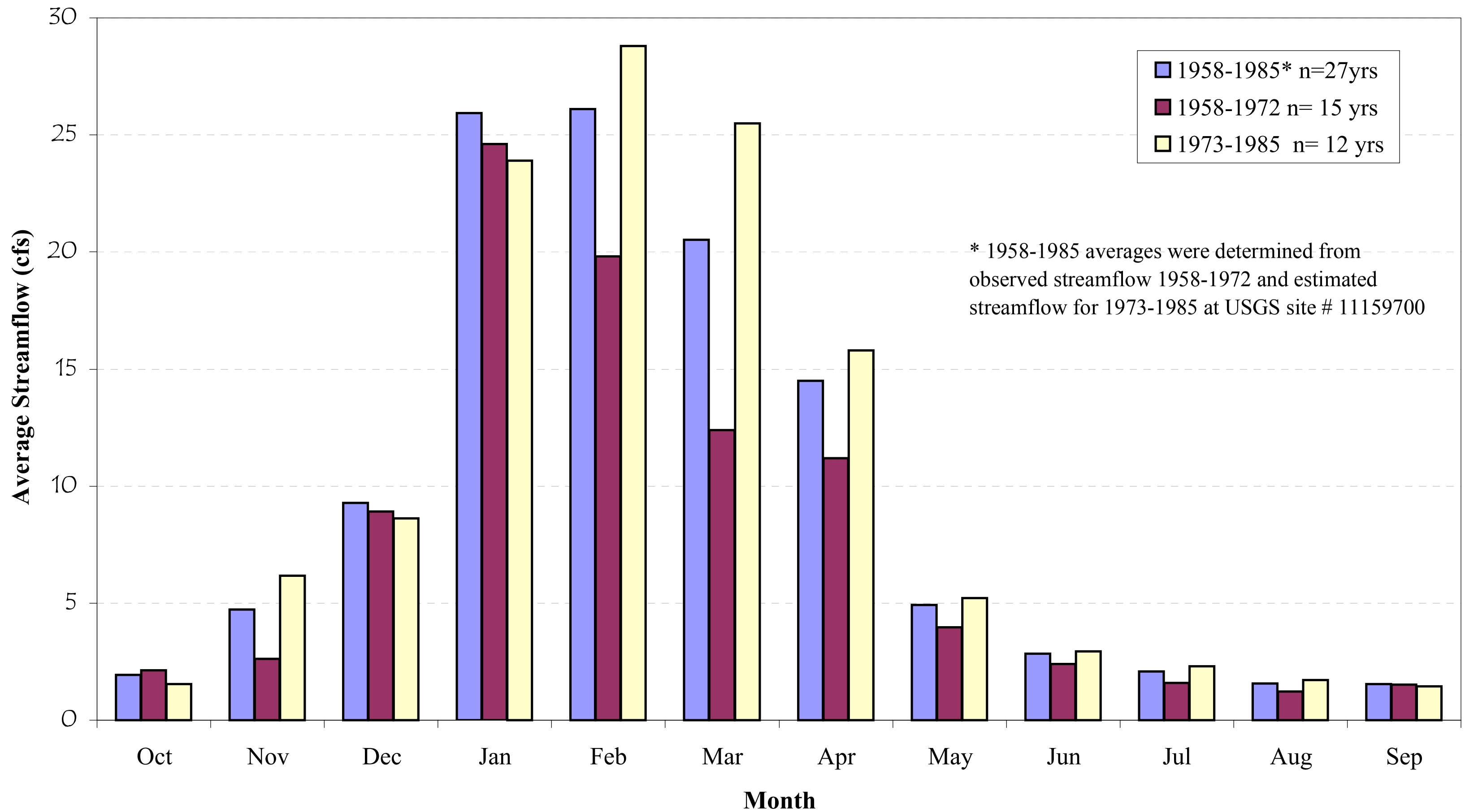

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Figure 10: Distribution of average monthly stream flow for Aptos Creek Tributary, based upon discharge measured and/or estimated at USGS gages #11159690 and #11159700.

Table 5: Monthly exceedance probabilities and estimated peak discharges for USGS gages #11159690 Aptos Creek near Aptos, CA (WY 1971-1985) and #11159700 Aptos Creek at Aptos, CA (WY 1958-1971). Exceedance probabilities are calculated by sorting all available mean daily flow values by month. Exceedance probabilities give information about how often a certain flow value is exceeded. For example, in August during a dry year, the flow exceeds 0.77 cfs 50% of the time and 0.67 cfs 90% of the time.

Month	Exceedance Probability	Wet	Average	Dry	Drought	Month	Exceedance Probability	Wet	Average	Dry	Drought
Oct.	95	2.1	0.94	0.69	0.51	Nov.	95	3.3	1.2	0.77	0.51
	90	2.1	1.0	0.70	0.55		90	3.4	1.3	0.78	0.56
	80	2.3	1.0	0.72	0.57		80	3.8	1.4	0.82	0.64
	70	2.3	1.0	0.74	0.60		70	4.3	1.5	0.85	0.67
	60	2.4	1.1	0.75	0.61		60	5.0	1.7	0.90	0.70
	50	2.6	1.2	0.77	0.61		50	6.4	1.8	0.95	0.70
Dec.	95	6.0	1.6	1.1	0.82	Jan.	95	15	2.3	1.5	0.91
	90	6.4	1.7	1.1	0.85		90	16	2.5	1.5	0.92
	80	7.5	1.8	1.2	0.86		80	20	2.7	1.6	1.0
	70	8.5	2.0	1.2	0.87		70	24	3.0	1.7	1.0
	60	10	2.5	1.2	0.92		60	30	3.4	1.7	1.0
	50	13	2.8	1.3	0.95		50	39	4.1	1.8	1.1
Feb.	95	22	3.6	2.2	1.0	Mar.	95	19	4.0	2.0	1.0
	90	24	3.9	2.2	1.1		90	20	4.4	2.1	1.1
	80	27	4.8	2.3	1.2		80	23	4.9	2.2	1.3
	70	32	5.4	2.4	1.3		70	26	5.6	2.3	1.4
	60	39	6.0	2.6	1.3		60	30	6.7	2.3	1.5
	50	48	6.7	2.8	1.4		50	35	8.1	2.4	1.6
April	95	12	2.9	1.6	1.1	May	95	5.8	1.8	1.2	0.82
	90	13	3.2	1.6	1.1		90	6.1	1.9	1.2	0.91
	80	14	3.8	1.7	1.1		80	6.7	2.2	1.3	1.0
	70	17	4.1	1.7	1.2		70	7.3	2.5	1.3	1.0
	60	21	4.7	1.9	1.2		60	8.0	2.8	1.3	1.0
	50	24	5.3	2.1	1.2		50	8.9	3.0	1.3	1.0
June	95	3.7	1.4	0.84	0.36	July	95	2.7	1.1	0.70	0.29
	90	3.8	1.5	0.85	0.38		90	2.8	1.2	0.73	0.48
	80	4.2	1.6	0.89	0.42		80	3.0	1.3	0.76	0.53
	70	4.6	1.7	1.0	0.55		70	3.1	1.4	0.79	0.54
	60	4.8	2.0	1.0	0.63		60	3.2	1.4	0.80	0.55
	50	5.0	2.2	1.1	0.70		50	3.4	1.6	0.84	0.58
Aug.	95	2.0	1.0	0.63	0.45	Sept.	95	1.8	0.87	0.63	0.46
	90	2.1	1.0	0.67	0.48		90	1.9	0.90	0.66	0.46
	80	2.2	1.0	0.68	0.48		80	2.0	1.0	0.69	0.47
	70	2.4	1.1	0.72	0.49		70	2.1	1.1	0.70	0.48
	60	2.4	1.2	0.75	0.49		60	2.1	1.1	0.70	0.49
	50	2.6	1.3	0.77	0.49		50	2.2	1.2	0.73	0.51

Since all existing hydrologic information is derived from USGS gage data on Aptos Creek upstream of the Valencia Creek confluence and extrapolations to Aptos Creek from an active stream flow monitoring program on Soquel Creek, attempts were made as part of this project to develop hydrologic data for a single season at key points in the watershed. Unfortunately, much of the data collected as part of this program was determined to be inaccurate due to a combination of unstable monitoring cross-sections and equipment failure. The best results were obtained on the mainstem of Aptos Creek at Spreckels Bridge near the mouth, where continuous water level data and a rating curve (**Figure 11**) with a reasonable level of confidence was used to develop a discharge hydrograph from mid-December to mid-March (**Figure 12**).

Also shown in Figure 12 is the hydrograph of estimated mean daily discharge for Aptos Creek at the abandoned USGS gage site based on extrapolations from the active Soquel gage site. Intuitively we would expect the extrapolated mean daily discharge values to be considerably lower, given the location of the gage site upstream of the Valencia confluence and the fact that the values represent mean daily discharge. This points to the fact that either our Spreckels results are underestimated, which is a distinct possibility given the lack of high flow measurements on the rating curve, or the extrapolated values from Soquel are overestimated. Either way, the value of the collected information is limited to a general understanding of the flow conditions present in 2001, with no ability to infer what flow conditions might be in Valencia Creek.

Flow measurements were also taken by SH&G staff and CWC volunteers over the course of the project to develop an understanding of the relative contributions of flow from each of the primary tributaries, including the mainstem of Aptos Creek at the Steel Bridge, the County Park and at Spreckels, Trout Gulch, and Valencia Creek at Valencia School and the Polo Fields (**Appendix B**). This data was also used to assess potential impacts of diversions, groundwater pumping, and sediment deposition on stream flow conditions through specific study reaches. Comparisons of the flow data collected by SH&G and CWC staff at the Valencia School, Aptos County Park, and Spreckels sites suggest there is no clear pattern of flow contribution from the tributaries. **Table 6** summarizes the results for these sites. Some of the observed disparity may relate to sandy bed conditions found throughout Valencia and lower Aptos. This aggraded channel condition results in shallow, spread out flow, a significant portion of which may be flowing subsurface through the sandy bed.

Table 6: Summary of same-day flow measurements at WY2002 stream flow monitoring sites.

Date	Aptos County Park	Valencia School	Spreckels Bridge	Ratio of County Park to Spreckels	Ratio of Valencia School to Spreckels
11/12/01	---	20.9	16.7	---	1.25
11/27/01	1.79	---	3.26	0.55	---
12/15/01	---	1.62	4.01	---	0.40
1/17/02	8.3	1.75	8.5	0.97	0.21
7/20/02	1.76	---	1.17	1.50	---
8/3/02	1.65	---	0.98	1.68	---
9/21/02	0.66	---	0.59	1.12	---

The observation of flow losses as result of subsurface flow is further supported by the synoptic flow studies conducted at two reaches. The first reach consisted of the section of channel on Aptos Creek between the Steel Bridge and the County Park. The second reach is on Valencia Creek between the Polo Fields and the Valencia School. The results for this study are presented in **Table 7**. Several data points were removed because they appeared to be outliers as a result of rainfall events. Loss of flow

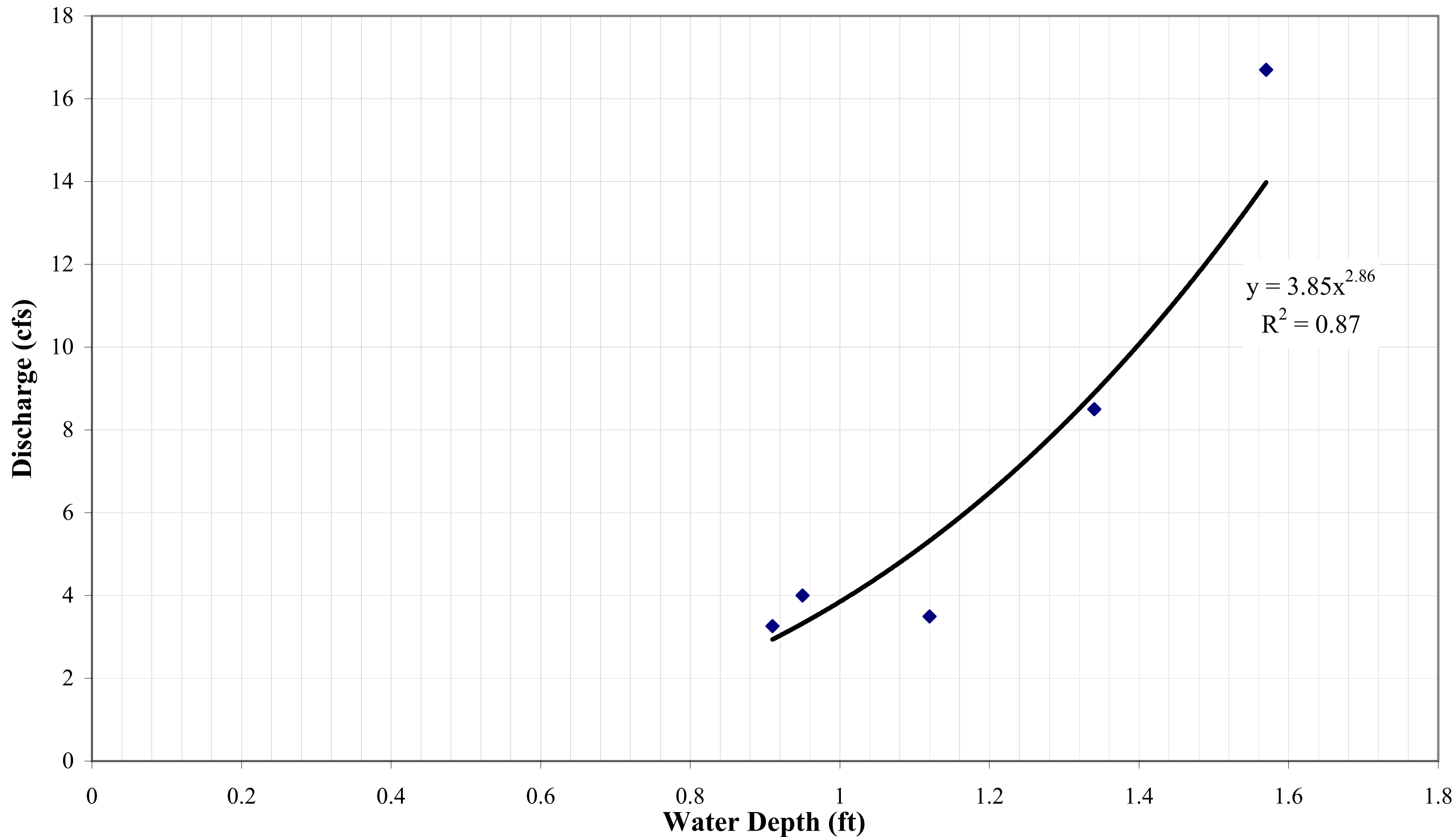

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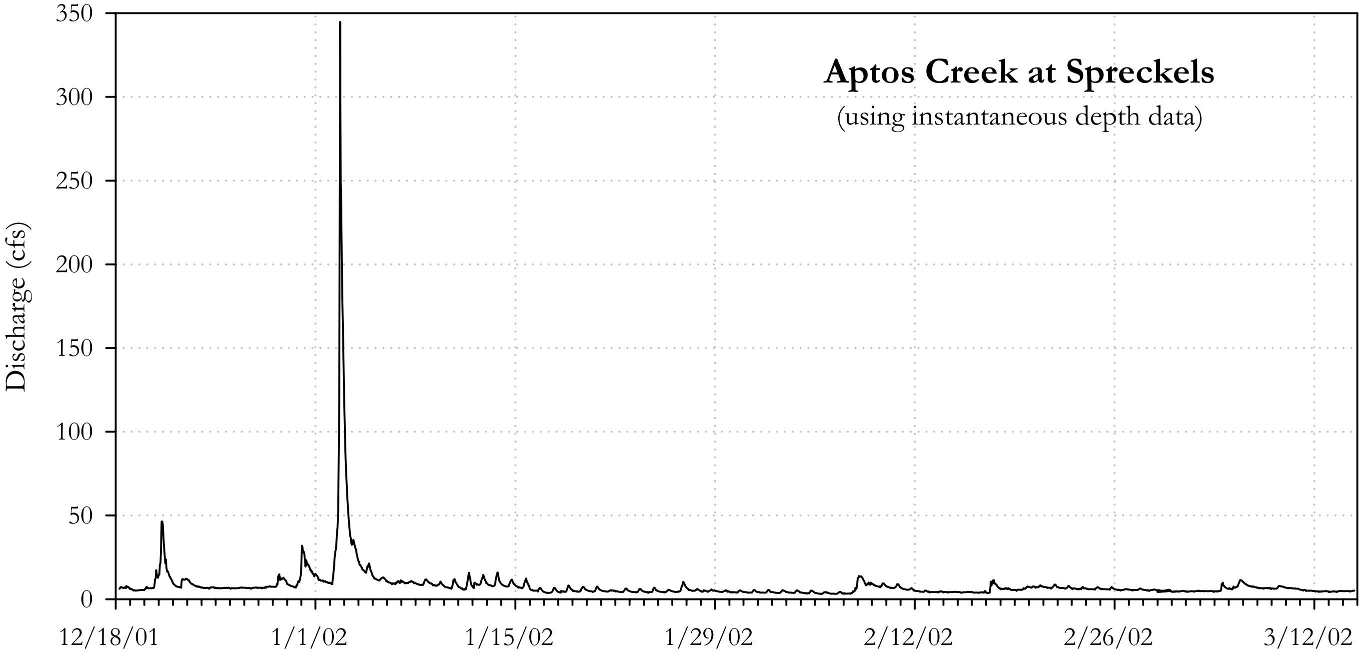
Figure 11: Water depth to discharge rating curve developed for Aptos Creek at Spreckels Drive. Water depth data collected from Global Water gage installed at site; discharge was measured in the field using standard USGS methods.



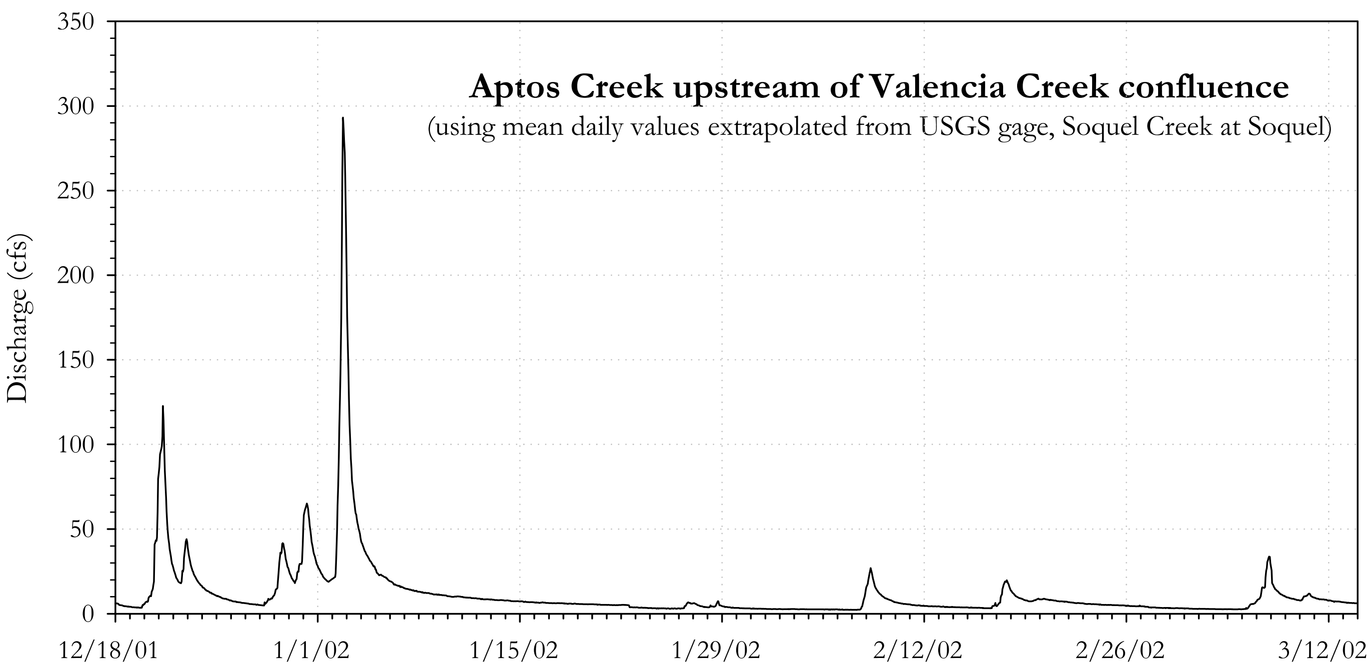


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Figure 12: Water year 2002 hydrographs for Aptos Creek Tributary and mainstem Aptos Creek at Spreckels Drive. Aptos Creek Tributary data is extrapolated from mean daily values from USGS gage #11160000, Soquel Creek at Soquel. Spreckels hydrograph is based on instantaneous flow data derived from rating curve shown in Figure 11.

Table 7: Synoptic flow results for Aptos Creek Watershed.

Tributary	Site	Date	Time	Measured by	Flow (cfs)	Gaining or Losing (cfs)	3-day rainfall total (in)*
Valencia	Upper Valencia Valencia School	12/8/01 12/8/01	9:25 10:55	CWC CWC	2.09 1.66	**-0.43**	0.01
Valencia	Upper Valencia Valencia School	1/19/02 1/19/02	9:40 10:45	CWC CWC	2.22 1.50	**-0.72**	0.00
Valencia	Upper Valencia Valencia School	3/9/02 3/9/02	9:25 10:35	CWC CWC	2.19 1.19	*storm runoff*	0.79
Valencia	Upper Valencia Valencia School	3/16/02 3/16/02	9:37 10:40	CWC CWC	1.45 1.04	**-0.14**	0.01
Valencia	Upper Valencia Valencia School	4/6/02 4/6/02	11:15 12:00	CWC CWC	1.30 0.82	**-0.48**	0.00
Aptos	Steel Bridge Aptos County Park	10/6/01 10/6/01	10:00 11:20	CWC CWC	1.40 1.28	**-0.12**	0.00
Aptos	Steel Bridge Aptos County Park	10/27/01 10/27/01	9:30 11:15	CWC CWC	1.30 1.15	**-0.15**	0.00
Aptos	Steel Bridge Aptos County Park	11/10/01 11/10/01	9:30 11:10	CWC CWC	1.30 1.44	0.14 +	0.46
Aptos	Steel Bridge Aptos County Park	1/12/02 1/12/02	9:29 11:59	CWC CWC	7.37 9.70	2.34 +	0.00
Aptos	Steel Bridge Aptos County Park	3/1/02 3/1/02	8:54 9:50	CWC CWC	4.58 4.74	0.16 +	0.00
Aptos	Steel Bridge Aptos County Park	3/29/02 3/29/02	9:08 10:00	CWC CWC	7.21 10.15	2.94+	0.00
Aptos	Steel Bridge Aptos County Park	5/1/02 5/1/02	9:20 10:00	CWC CWC	3.56 3.72	0.16+	0.15
Aptos	Steel Bridge Aptos County Park	6/1/02 6/1/02	9:30 10:56	CWC CWC	3.21 1.07	**-2.14**	0.01
Aptos	Steel Bridge Aptos County Park	6/22/02 6/22/02	9:10 10:15	CWC CWC	2.49 2.49	0.00	0.00

**Source: Daily precipitation totals from CIMIS gage #104, De Laveaga Park, Santa Cruz.*

between the upstream and downstream monitoring points appear to be more common in the Valencia reach, again, suggesting subsurface flow through sand substrate.

Shallow groundwater elevations will vary seasonally in the temperate climate of the Central California Coast. The shallow groundwater table meets the land surface at the local stream channel, thus maintaining surface water flow and annual or perennial streams. The elevation of the shallow groundwater table can have a direct influence on surface water flow volumes contained within local streams. Groundwater extractions from subsurface aquifers can have an impact on the surface water volumes when there is no impermeable clay layer to separate the shallow groundwater table from the deeper water bearing aquifers. The specific hydrogeology of the Aptos Creek Watershed is complex and there may be interspersed confining layers beneath the local area. A detailed investigation of the local hydrogeology and various water bearing zones was outside the scope of this document, but we believe it is prudent to consider the potential impacts of groundwater extractions by local water agencies and private landowners on the surface water hydrology of the Aptos Creek Watershed. The main purpose of this discussion is to suggest that there is a potential for reductions in baseflow volumes within local streams as a result of groundwater extractions. Future studies, focused directly on groundwater impacts, should be pursued.

Water extraction in the Aptos Creek Watershed varies from year to year depending on the amount of rainfall received the previous winter and the weather patterns occurring in the spring, summer, and fall. This typical pattern is clearly illustrated by use data provided by the Soquel Creek Water District (SCWD), the primary water supply agency within the Aptos Creek Watershed (**Figure 13**). This seasonal trend of increased removals during the dry months is likely representative of the other water users in the watershed, including the Central Water District, private wells, and those who exercise their riparian rights.

The SCWD's water supply comes primarily from groundwater within the Aptos Creek and Soquel Creek Watersheds, with 16 active water supply wells meeting the needs of over 45,000 people from Capitola to La Selva Beach. Two-thirds of the approximately 5,000 ac-ft of water per year is provided by the Purisima Aquifer to the west and the remaining one-third from the Aromas Red Sands aquifer to the south. Valencia Creek separates these two geologic units. Central Water District also derives water from the Purisima and Aromas Red Sands Aquifers, almost exclusively from within the Valencia Creek Watershed. Recent reports of declining water supply from both the Purisima and Aromas Red Sands Aquifers suggest sustainable levels of water withdrawal from these aquifers may have been exceeded, prompting an ongoing effort to secure a supplemental water supply to preserve the groundwater quality of the local area. In addition to the SCWD wells, there are over 1,300 private wells pumping water from the Aptos/Soquel groundwater basin (SCWD 1998) that do not maintain public removal records. The County of Santa Cruz GIS indicated records for approximately 250 private wells in the Aptos/Valencia Creek Watersheds.

The following discussions and data are focused around records provided by SCWD. It must be kept in mind that: (1) these are the only detailed pumping records available to the public for groundwater extractions in the Aptos area and (2) there is a strong potential that the SCWD wells may be extracting water from a confined aquifer that would have minimal influence on the shallow groundwater elevations and surface water base levels. The purpose of this data presentation is to address the potential impact of groundwater removal on baseflow hydrology and potentially to improve the collective management of water resources.

According to the pumping records provided by SCWD, in 1996 the SCWD extracted a total of 5,480 ac-ft, exceeding the estimated sustainable yield of the two combined aquifers (4,810 ac-ft per year) by 610 ac-ft. There are three wells located within the physical lay of the Aptos Creek Watershed and are

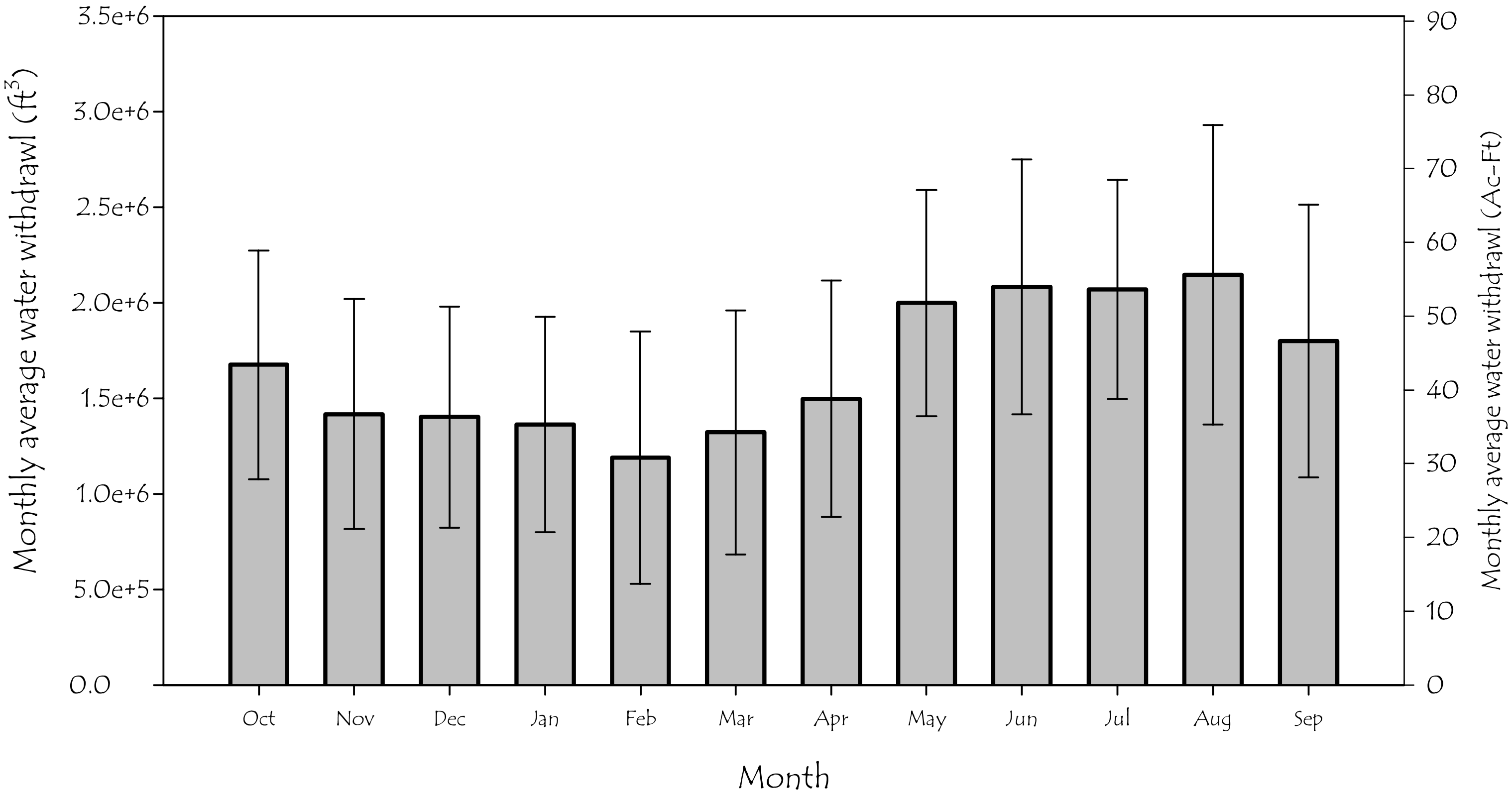


Figure 13: Monthly average water extraction by Soquel Creek Water District from wells located within Aptos Creek Watershed. Data was provided by SCWD and is the average of the sum of monthly water removal from Aptos Creek Well, T. Hopkins Well, and Ledyard Well. This seasonal trend of water removal is most likely representative of private extractions and surface water diversions, as well.

indicated on Figure 2. A comparison of the total 1996 water removal for the entire SCWD to the total water extracted from T. Hopkins, Ledyard and Aptos Creek Wells (650 ac-ft), indicates approximately 12% of the 1996 water was supplied from wells located beneath the Aptos Creek Watershed (**Figure 14**). Estimates from Santa Cruz County also suggest that approximately 1,000 ac-ft per year of the total volume extracted is returned to the basin as a result of the prevalence of septic use throughout the Aptos and Soquel Watersheds.

There is still little definitive evidence of the detailed interactions and connections between surface water and groundwater in the Aptos Creek Watershed. The intent of the information presented in this report is to encourage a collective process that addresses the potential for improving low flow conditions in the local stream channels for anadromous fish habitat and considers the potential factors that can be modified to improve instream flow conditions.

The watershed areas of the two main tributaries of Aptos Creek Watershed, Aptos Creek and Valencia Creek, are relatively similar yet their hydrologic conditions appear to be significantly different. These hydrologic differences are the result of different land uses, the underlying soil and geologic characteristics, and the dominance of sandy bed conditions in the Valencia subwatershed. The impact of land-use, such as an increase in impervious surfaces resulting in increased runoff during low to moderate magnitude rainfall events, is difficult to quantitatively assess given the lack of long-term, high quality, high resolution discharge data. To determine the potential impact of impervious surfaces, the approach would need to compare pre-development with post-development conditions, rather than comparing rainfall-runoff responses between Aptos and Valencia.

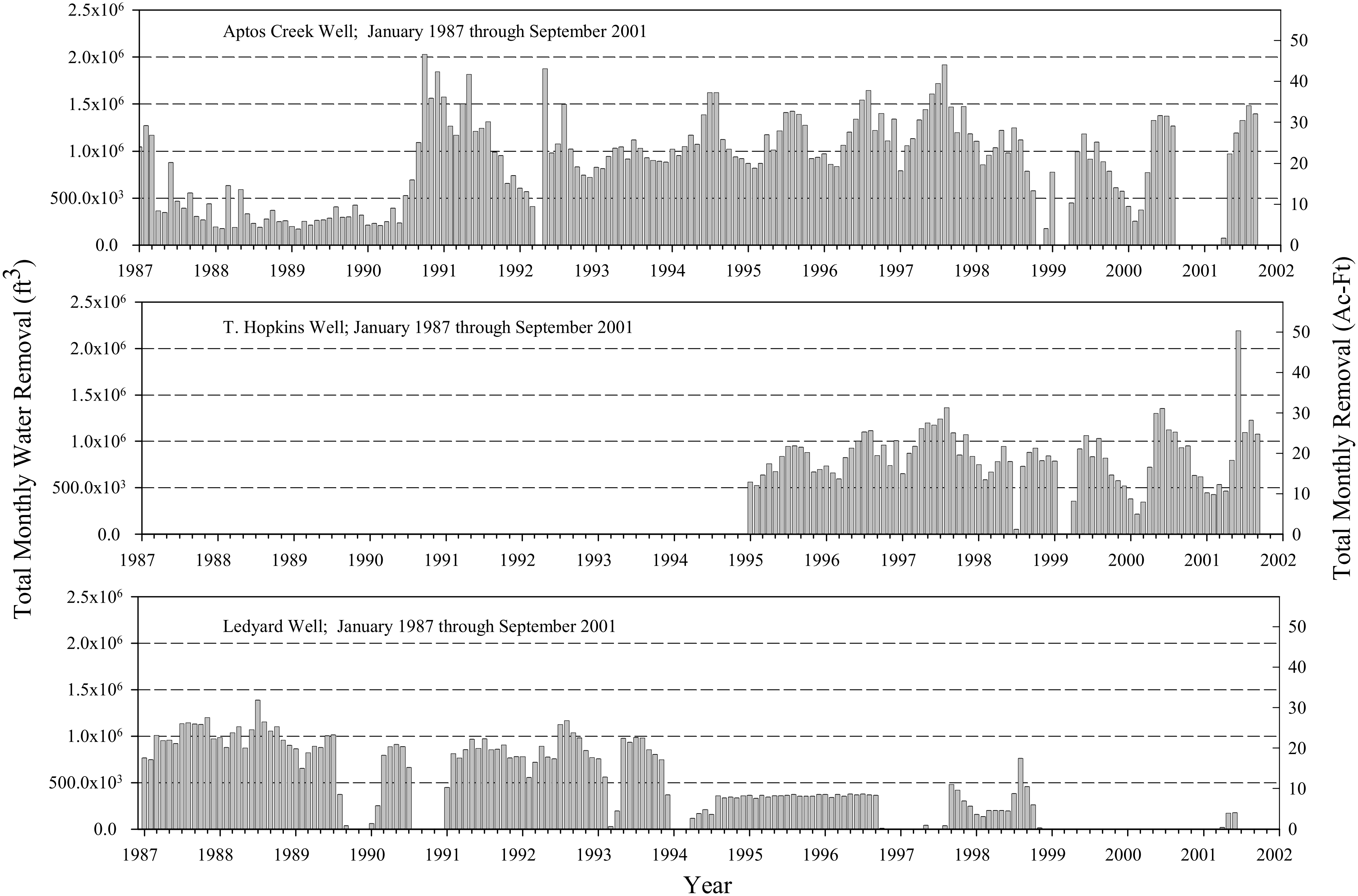
Regardless of the lack of quantitative data to assess impervious surface impacts, inferences can be made based on observed and measured geomorphic conditions in the channel (*see Geomorphology and Sediment Source Technical Memorandum*) and discussions of studied and modeled impacts related to urbanizing watersheds. In a forested watershed like Valencia, where the soils are extremely sandy, the expected runoff coefficient would be low under natural conditions. By adding many miles of roads, driveways, roofs, and other impervious surfaces, the runoff coefficient would be much higher, especially during low to moderate intensity rainfall events, significantly increasing the amount of water delivered directly to the stream channel.

3.2 – WATER QUALITY

The Aptos Lagoon accepts all of the point source and non-point source pollution that is introduced into the local waterways. The fertilization of surface waters with nutrients results in a significant increase in biological growth of algae and phytoplankton, known as eutrophication. When the lagoon mouth is open, water circulation allows the system to handle excess nutrient inputs without a severe eutrophic response. As sand deposition increases and freshwater discharges decrease in the spring and summer, a sandbar forms at the mouth and isolates the lagoon from the ocean. During the 2002 water year, a sandbar formed at the mouth of the creek and isolated the Aptos Lagoon from the ocean six times, with one sustained closure lasting over 36 days. As **Figures 15** and **16** illustrate, the bottom and surface waters in a closed coastal lagoon behave differently. The water temperature, salinity and DO values in early October are very different in Figure 15 than in Figure 16, even though the physical conditions in the lagoon had not changed and the sandbar remained intact. The reason for the differences in the surface waters and bottom waters is explained by the following.

The salt water trapped within the lagoon is denser than the freshwater inflows, thus forming the bottom layer of the water column, as observed in the salinity plots of Figures 15 and 16. Photosynthesis produces biomass and oxygen in the surface waters. The amount of algae (biomass)

Figure 14: Total monthly groundwater withdrawal by Soquel Creek Water District from Aptos Creek Watershed



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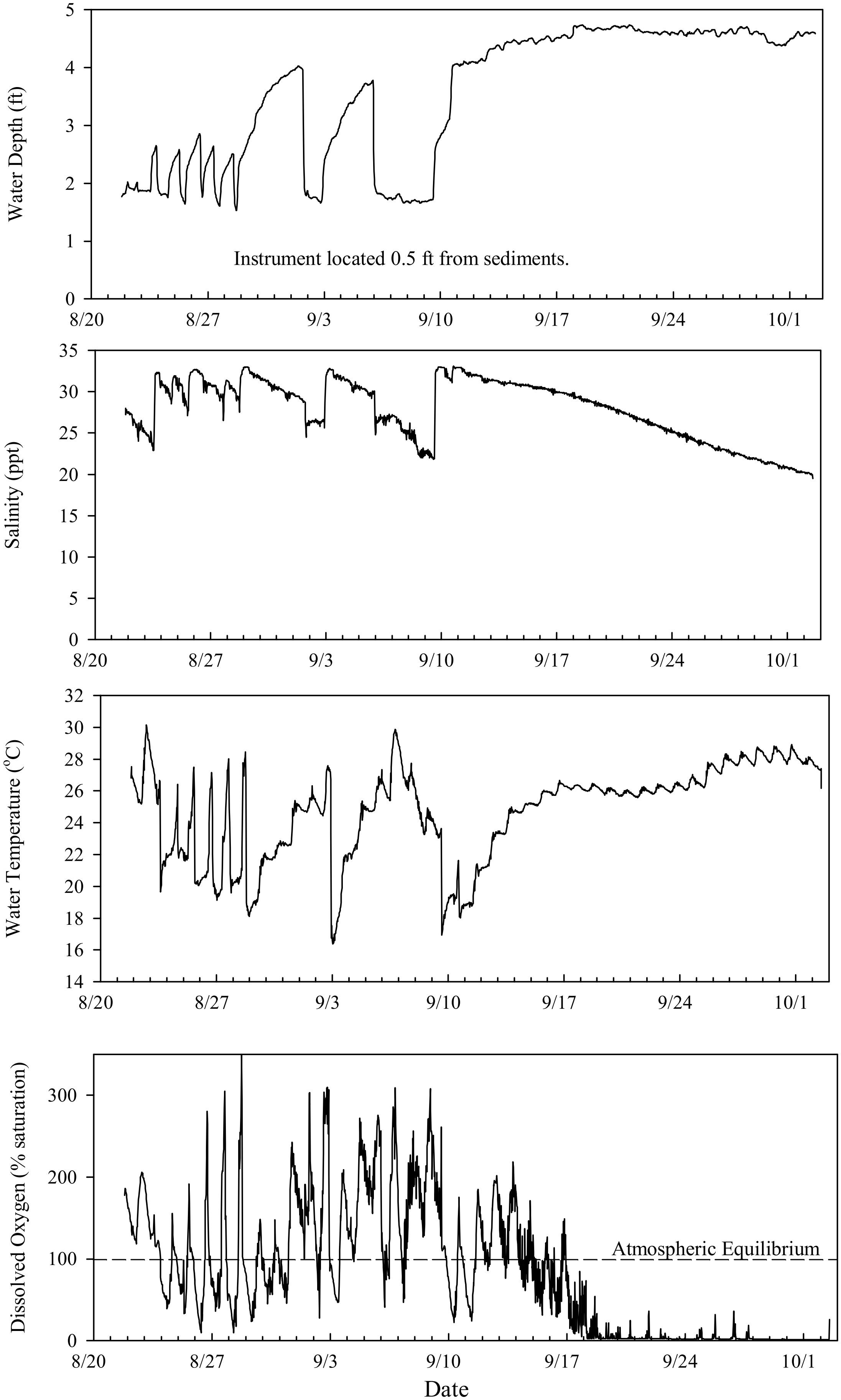

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Figure 15: Water quality data collected by YSI in Aptos Creek Lagoon, August 21 - October 2, 200. Instrument is located in bottom waters.

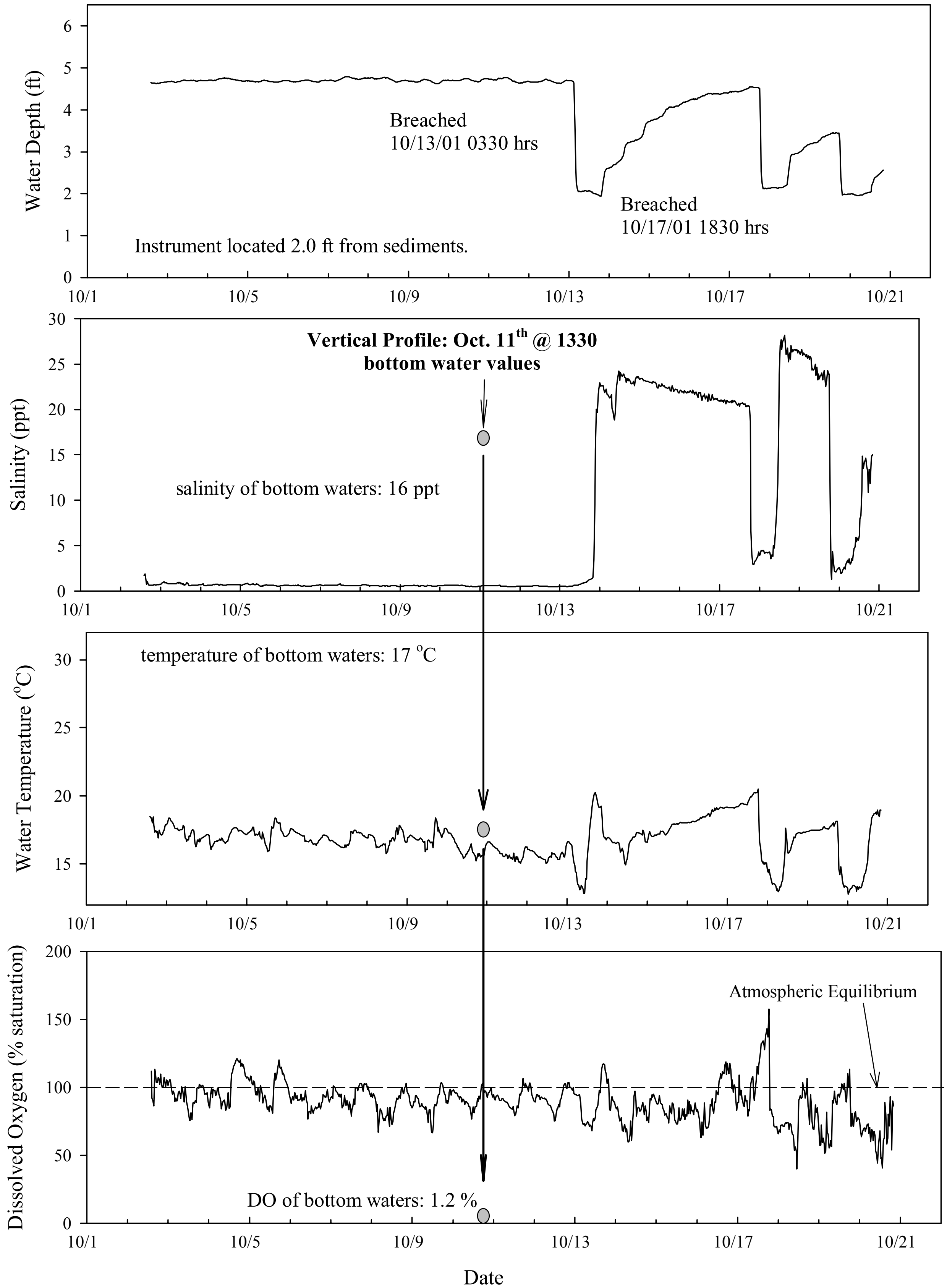

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Figure 16: Water quality data collected in Aptos Creek Lagoon, October 2-October 21, 2001. Instrument located in the middle of the water column.

produced is directly dependent upon the supply of nutrients (N and P). The larger the nutrient supply, the greater the algal bloom. The algae subsequently sink to the bottom and are respired by bacteria, consuming oxygen in the process. Anoxic conditions (devoid of dissolved oxygen) develop in the bottom and pore waters (water in the surface sediments) as a result of bacterial breakdown of sinking organic detritus, such as algae.

The temperature and salinity differences between the surface and bottom water physically and chemically isolate these two water bodies from one another. This isolation prevents oxygen that is produced in the surface water by photosynthesis during the daylight hours to be available for respiration in the bottom waters. This is evident in Figure 15 from September 18th through October 2nd when the entire reservoir of oxygen in the bottom waters has been consumed. In fact, spot measurements of the DO concentrations in the bottom waters on October 11th confirmed the continued suppression of the DO levels in the bottom waters (Figure 16). Once the entire reservoir of oxygen has been consumed in the bottom waters, heterotrophic[1] bacteria will continue to oxidize organic matter by utilizing oxygen alternatives. The oxygen alternatives include sulfate (HSO_4^-), the most abundant substitute, nitrate (NO_3^-), and manganese oxide (MnO_2). When reduced, sulfate forms hydrogen sulfide (HS^-), which is toxic to fish and invertebrates. While no measurements of the HS^- levels were conducted within Aptos Lagoon during the sustained closure in the fall of 2001, it is a reasonable assumption that HS^- may have been produced sometime during 25 days of anoxic conditions. These reduced conditions can also result in high concentrations of ammonia in the water column, also toxic to aquatic organisms in high doses.

Water samples collected within the four local lagoons indicate that Aptos Lagoon is enriched in biologically available nutrients, particularly phosphate (**Figure 17**)[2]. Other water quality data has suggested that there may be an additional source of nutrients to the lagoon that is not coming from the local tributaries. The vertical profiles indicated a distinct halocline at a depth of 3 ft and anoxic conditions in the bottom waters due to extreme water temperatures exceeding 25°C and excessive biomass loading from the surface waters (**Figure 18**). Another vertical profile at the location of the YSI on October 11th illustrated the sustained anoxic bottom waters. The vertical profile results further support that when closed, Aptos Lagoon is a hypereutrophic and vertically stratified water column with compromised water quality conditions.

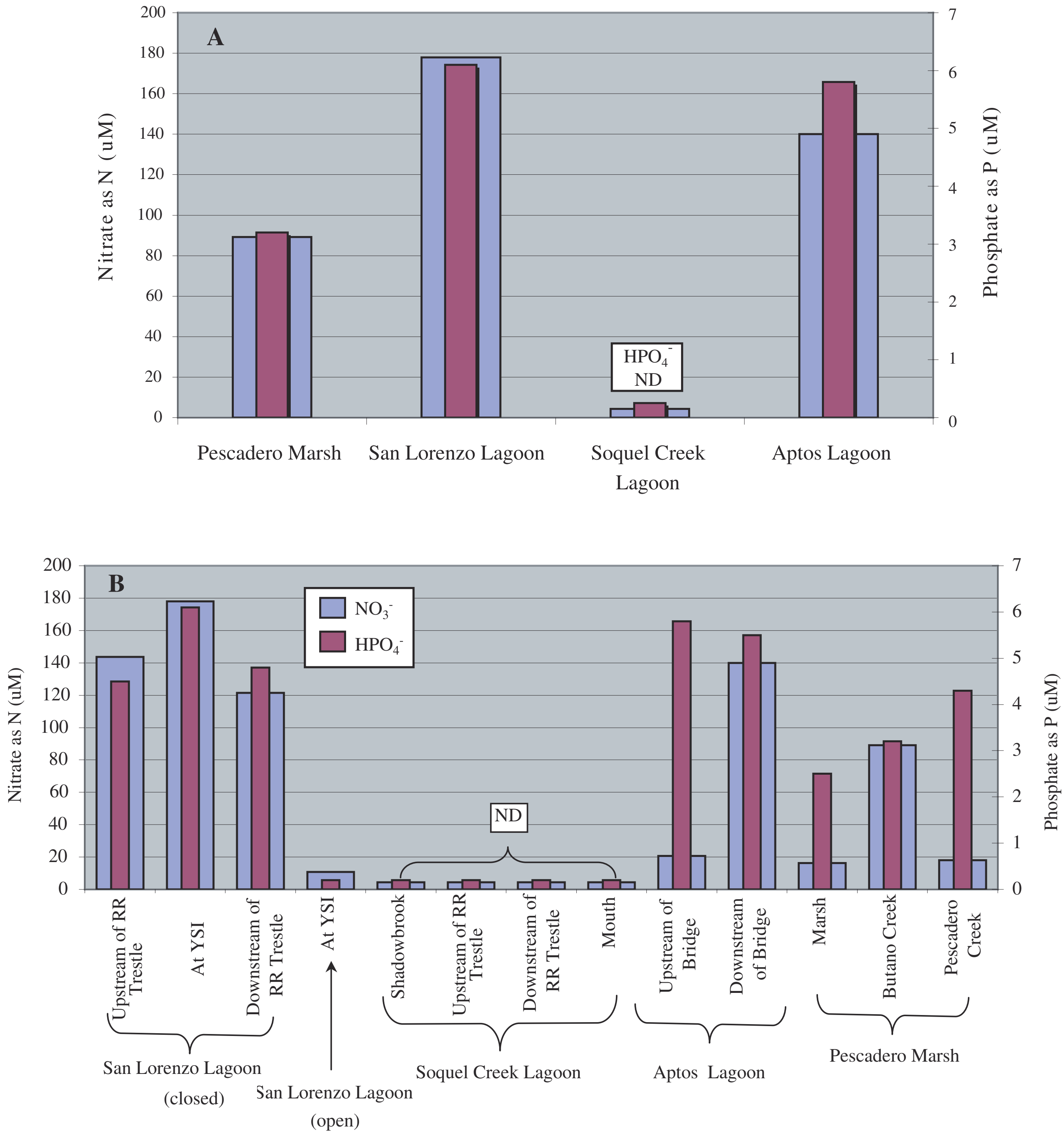
The results of the recent Surfrider monitoring inspired a further investigation concerning the historical distribution of fecal coliform levels observed within the Aptos Creek Watershed. The Santa Cruz County Environmental Health Department has been collecting fecal coliform samples within Aptos Creek Watershed for over two decades and provided us with their data. **Figure 19** is a summary of the long-term data set of monthly fecal coliform results for the past 17 years. Figure 19 graphically presents the data results from the four main tributaries. While there are data gaps at all of the stations, it is evident that a significant proportion of the fecal coliform from the overall watershed originates in the Valencia Creek Watershed. **Figure 20** compares the coliform levels detected in mainstem Aptos Creek to those detected at the mouth of the watershed. The alarming, order of magnitude higher levels observed at the mouth suggest a source of pollution to the lagoon waters downstream of the Spreckels Drive crossing. Suggestions have been made that a leaky sewer line may be the chronic source and efforts should be undertaken to identify and remediate the problem.

As part of the weekly stream monitoring program conducted by the CWC volunteers, ancillary water quality data was collected simultaneously (**Table 8**). Ancillary parameters can provide meaningful

[1] Heterotrophic bacteria breakdown organic matter, i.e. respire such things as phytoplankton, algae, leaf litter, etc. and return the inorganic constituents back into the environment.
[2] Sample concentration units have been converted to uM to allow direct comparison of N and P ratios. 100 ug/L NO_3^- -N = 70uM; 100 ug/L HPO_4^- -P = 3.2 uM.

information in compromised water columns that have significant biological growth (as illustrated above from the lagoon ancillary data). However, the water column within a stream is well-mixed and well-oxygenated, therefore the ancillary parameters will rarely indicate decreased oxygen or increased water temperatures. The simple process of water circulation can allow a body of water to suppress the potential negative effects of nutrient enrichment because water temperatures are kept lower than if the water were stagnant, and turbidity associated with even slightly flowing water prevents the production of phytoplankton and other algal species. Therefore it is no surprise that the ancillary water conditions observed within Aptos and Valencia Creeks reflect healthy and normal stream conditions.

In order to increase the effectiveness of 'watershed' enhancement efforts, the improvement of the coastal lagoon function should be considered when addressing future watershed management efforts. Adaptive management that focuses on enhancing the health of the summer lagoon system will undeniably benefit the survival, growth and migration of the local anadromous fish populations. The current condition of the lagoon is compromised, both from a physical and water quality perspective. Assuming that the Aptos Lagoon extends from Spreckels Road to the Monterey Bay, over 70% of the Lagoon is devoid of riparian vegetation and cover. Nutrient and fecal coliform samples collected within the lagoon and to a lesser extent, the associated tributaries, indicate a eutrophic (nutrient-enriched) lagoon system. When the summer lagoon forms by the sandbar closure at the mouth, the exposed brackish water atop beach sand results in elevated water temperatures. The water quality in the bottom waters displays a sustained level of anoxia, unsuitable for fish and invertebrates.



0.1 mg/L NO_3-N = 70 uM
0.1 mg/L HPO_4^--P = 3.2 uM

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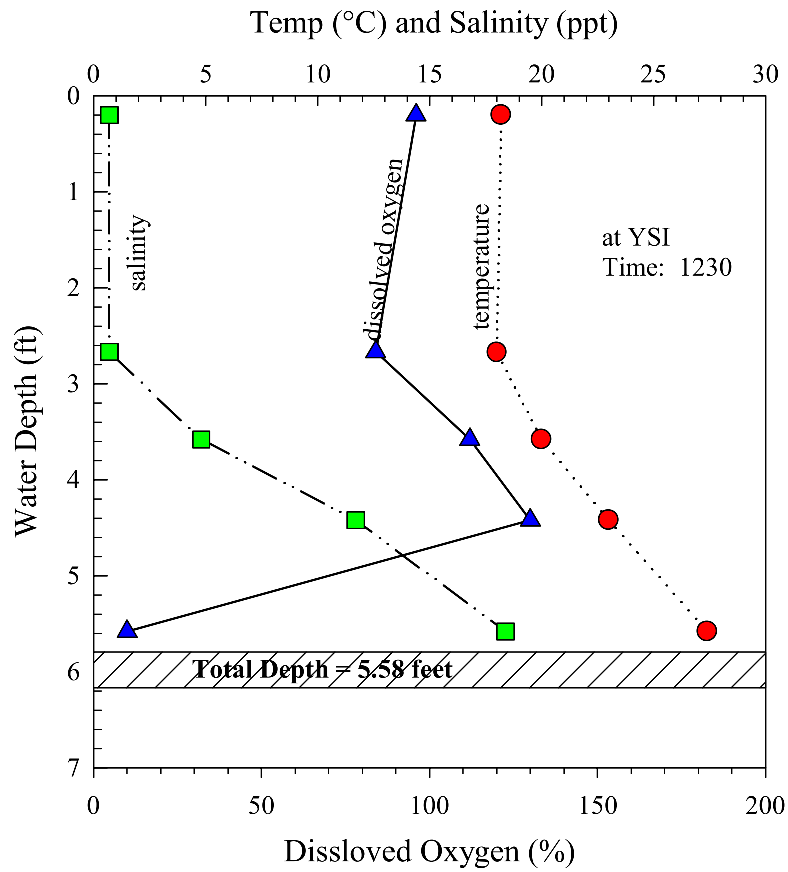
Figure 17A: Comparison of maximum values of nitrate and phosphorus in Central California lagoons during the Fall of 2001. **B**: Concentration of NO_3 and HPO_4 in Central California coastal lagoons.



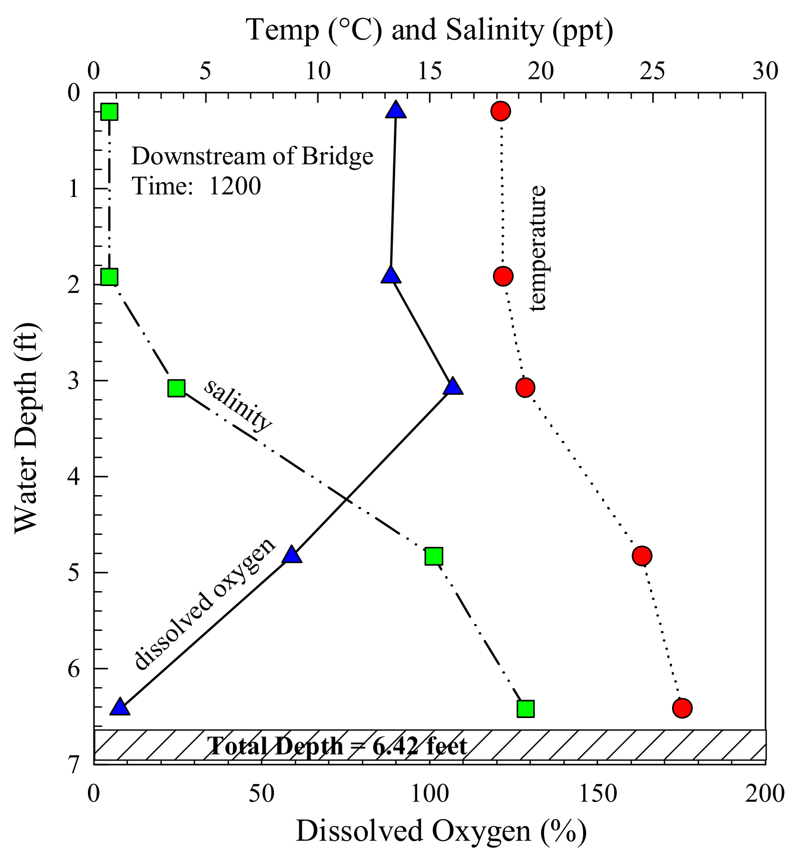


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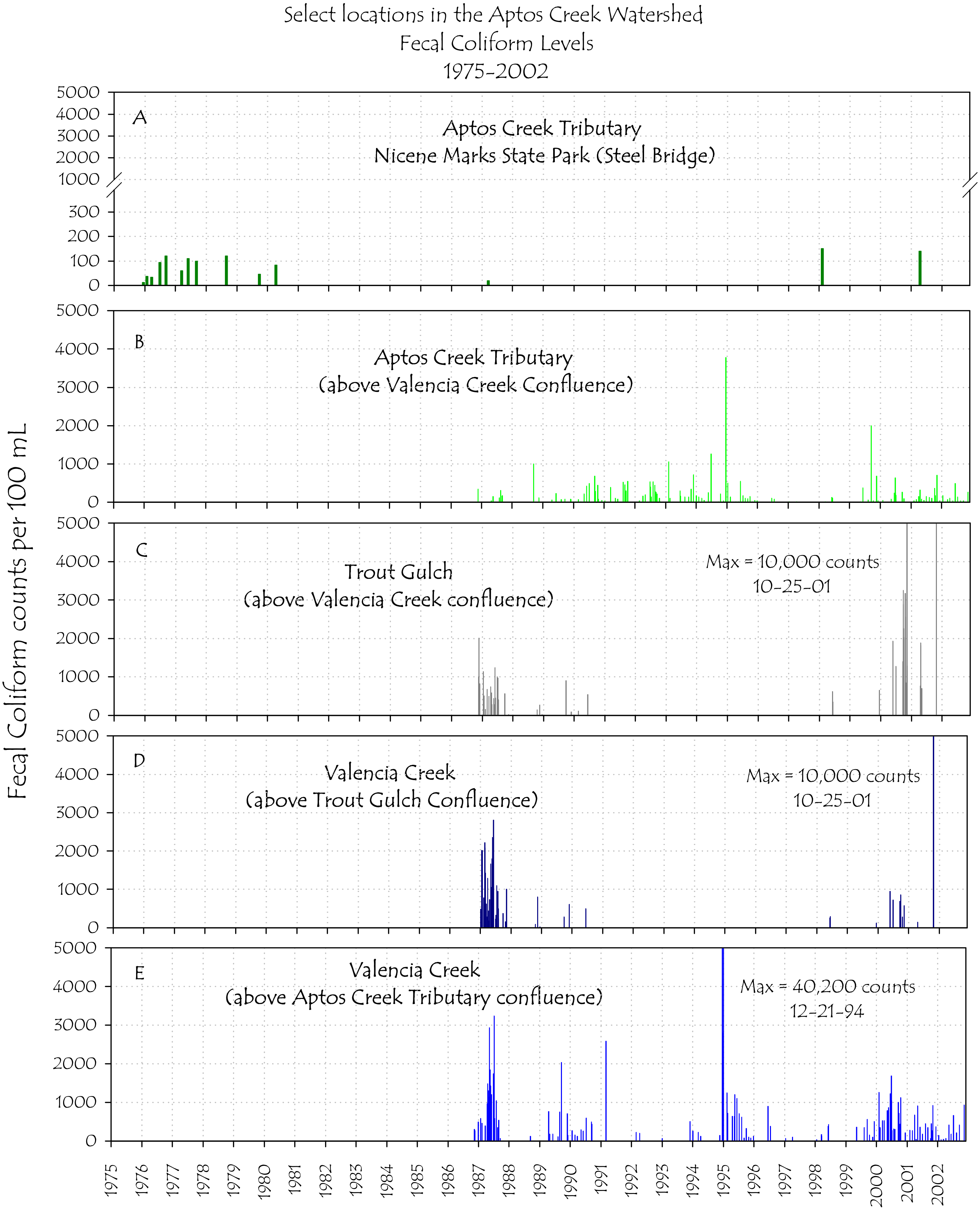
Figure 18: Vertical profile of Aptos Lagoon, October 2, 2001.



Figures 19 A-E: Fecal coliform counts determined in water samples collected from various locations within the Aptos Creek watershed. Notice the elevated concentrations of fecal coliform detected in the Valencia Creek and Trout Gulch watersheds relative to those observed in the Aptos Creek Tributary.
(*Data provided by the Santa Cruz County Environmental Health Department*)

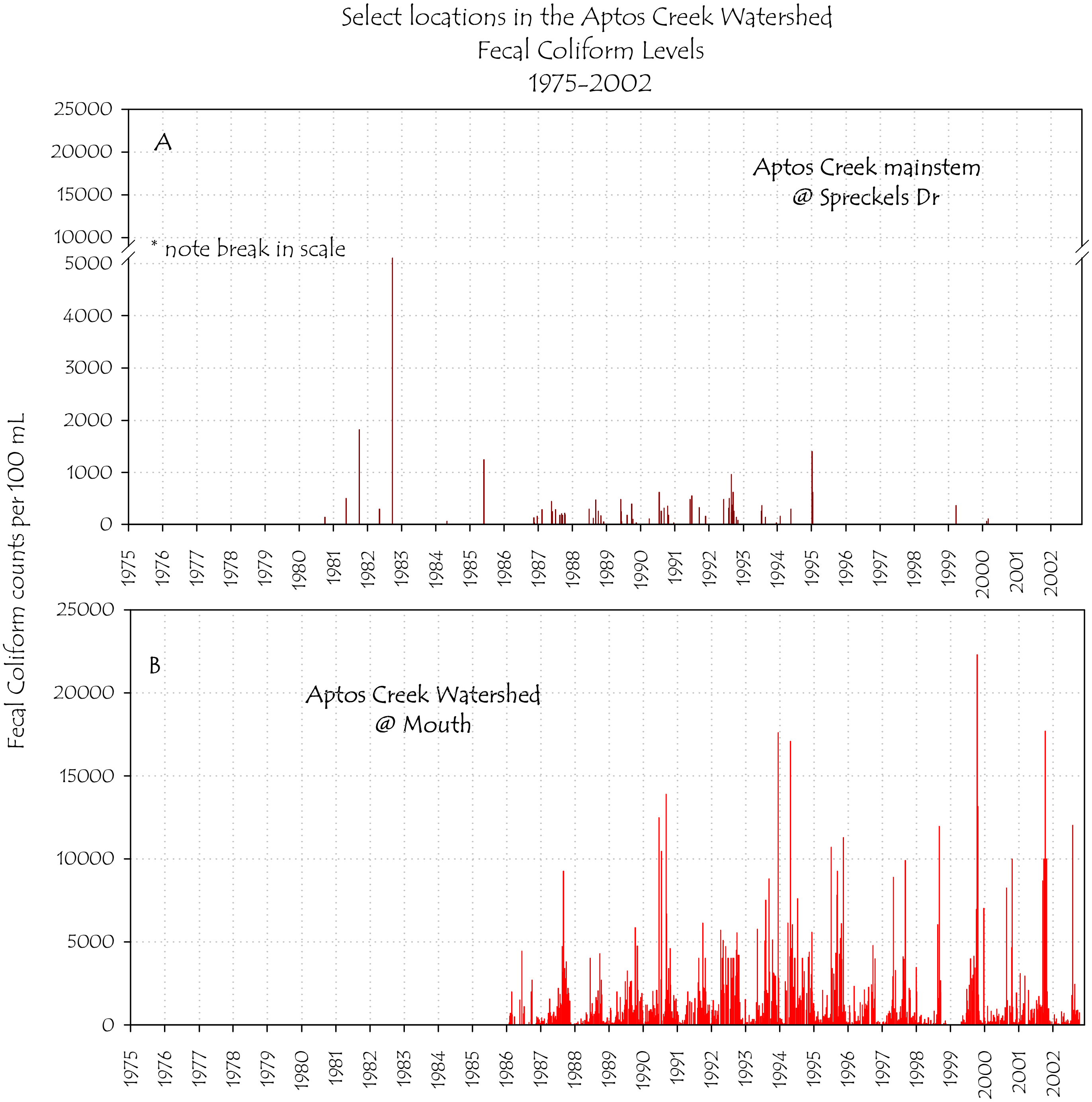


Figure 20 A. The consistently lower fecal coliform levels observed in the Aptos Creek mainstem approximately 1/4 mile downstream from the confluence of Aptos Creek Tributary and Valencia Creek indicates the dilution of elevated fecal coliform concentrations observed in Valencial Creek by the relatively greater water volumes and lower fecal levels in the Aptos Creek Tributary.

Figure 20 B: Fecal coliform levels over 5x as high as any other site (including Spreckels), suggests a chronic source of fecal coliform and nutrients is present in the Lagoon area. Efforts should be made to identify and remove this source .
(*Data provided by the Santa Cruz County Environmental Health Department*)

Table 8: Water quality data collected by CWC staff and volunteers.

Date	SiteName	Time	Weather	Air Temp (C)	Water Temp (C)	Conductivity (mS)	Turbidity (0=<5 JTU unless noted)	Dissolved Oxygen (mg/L)	pH
09/22/01	Steel Bridge	11:00	Clear	14.1	12.1	1.00	clear	9.82	8
09/26/01	Aptos Co. Park	10:10	Clear	17.3	13.2	0.90	clear	7.96	7.5
09/26/01	Spreckels Bridge	12:00	Clear	17.1	14.8	0.80	clear	8.24	7.5
10/06/01	Steel Bridge	10:00	Cloudy	14.1	15.0	0.80	clear	10.3	7.8
10/06/01	Aptos Co. Park	11:20	Cloudy	14.7	14.0	0.80	clear	9.6	7.5
10/13/01	Valencia School	10:46	Clear	13.2	10.8	0.50	clear	10.1	7.5
10/13/01	Polo Grounds	9:28	Clear	10.5	10.3	0.50	clear	10.5	7.5
10/27/01	Steel Bridge	9:30	Cloudy	10.7	10.9	0.80	clear	10.2	8
10/27/01	Aptos Co. Park	11:15	Cloudy	14.6	11.5	0.80	clear	10.3	8
11/03/01	Valencia School	10:30	Fog	13.0	12.0	0.50	clear	10.1	7.5
11/03/01	Polo Grounds	9:34	Fog	11.2	11.3	0.50	clear	9.8	7.5
11/10/01	Steel Bridge	9:30	Cloudy	9.6	9.5	0.80	clear	11.2	7.5
11/10/01	Aptos Co. Park	11:10	Cloudy	15.8	10.6	0.80	clear	10.0	7.5
11/10/01	Mangels Gulch	10:55	na	na	na	na	na	na	na
12/01/01	Steel Bridge	9:20	Rain	8.8	8.4	0.70	clear	10.4	7.5
12/01/01	Valencia School	10:36	na	10.1	9.0	0.50	cloudy	11.0	7.5
12/05/01	Mangels Gulch	11:20	na	na	na	na	na	na	na
12/08/01	Valencia School	10:55	Clear	8.7	8.0	0.50	cloudy	10.6	7.6
12/08/01	Polo Grounds	9:25	Clear	5.5	7.7	0.50	cloudy	12.3	7.5
12/15/01	Spreckels Bridge	11:40	Clear	9.5	6.6	0.40	cloudy	11.7	7.5
12/15/01	Valencia School	9:40	Clear	4.3	5.4	0.40	cloudy	11.5	7.5
01/02/02	Steel Bridge	10:06	Clear	3.0	4.0	0.50	clear	1.0	7.5
01/05/02	Steel Bridge	9:30	Cloudy	7.1	8.8	0.30	cloudy	11.6	7.5
01/05/02	Aptos Co. Park	11:30	Cloudy	14.0	10.0	0.30	cloudy	9.5	7.5
01/12/02	Steel Bridge	9:29	Clear	5.0	8.0	na	clear	10.8	7.5
01/12/02	Aptos Co. Park	10:59	Clear	10.2	8.5	na	clear	11.8	7.5
01/19/02	Valencia School	10:45	Clear	3.3	3.9	na	clear	13.4	7.5
01/19/02	Polo Grounds	9:40	Clear	1.5	4.1	na	clear	13.2	7.5
01/31/02	Spreckels Bridge	15:25	Clear	na	na	na	clear	na	na
02/02/02	Aptos Co. Park	11:30	Clear	8.0	5.0	1.40	clear	13.3	7.5
02/16/02	Valencia School	9:50	Clear	10.0	8.4	0.50	clear	10.9	7.5
02/16/02	Polo Grounds	11:30	Clear	11.4	9.4	0.50	clear	10.8	7.5
03/01/02	Steel Bridge	8:54	Clear	6.5	8.5	0.70	clear	11.8	8
03/01/02	Aptos Co. Park	9:50	Clear	13.0	9.5	0.70	clear	12.3	7.5
03/09/02	Valencia School	10:35	Hazy	11.0	7.1	0.40	clear	10.9	7.5
03/09/02	Polo Grounds	9:25	Hazy	6.8	6.7	0.50	cloudy	11.4	7.5
03/16/02	Polo Grounds	9:37	Cloudy/windy	9.2	9.7	0.50	clear	12.1	7.5
03/16/02	Valencia School	10:40	Clear/windy	10.4	7.3	0.50	clear	10.6	7.5
03/21/02	Spreckels Bridge	12:10	Clear	15.4	11.9	0.60	clear	11.3	7.5
03/29/02	Aptos Co. Park	10:00	Clear	14.0	11	0.60	clear	11.1	7.5
03/29/02	Steel Bridge	11:55	Fog	12.0	10.5	0.6	clear	10.9	7.5
04/06/02	Valencia School	12:00	Cloudy	15.1	12.7	0.5	clear	9.7	7.5
04/06/02	Polo Grounds	11:15	Cloudy	14.5	12.1	0.6	clear	10.4	7.5
05/01/02	Aptos Co. Park	10:00	Cloudy	11.0	10	0.7	clear	16.2	7.5
05/01/02	Steel Bridge	9:20	Cloudy	10.0	9	0.7	clear	11.4	7.5
05/04/02	Valencia School	10:00	Fog	12.0	9.5	0.6	na	10.9	7.5
05/04/02	Polo Grounds	9:20	Fog	10.0	9	0.6	na	11.2	7.5
06/01/02	Aptos Co. Park	10:56	Fog/clear	13.0	14	0.8	cloudy	10.3	7.5
06/01/02	Steel Bridge	9:30	Cloudy/lt rain	12.0	14	0.8	clear	10.0	7.5
06/08/02	Valencia School	9:37	Clear	12.0	12.5	0.6	clear	11.1	7.5
06/08/02	Polo Grounds	10:30	Clear	19.0	12.5	0.8	clear	10.5	7.5
06/22/02	Aptos Co. Park	10:15	Clear	13.5	14	0.8	clear	9.6	8
06/22/02	Steel Bridge	9:10	Cloudy	14.0	13	0.9	clear	9.2	8
06/30/02	Spreckels Bridge	10:20	Clear	17.0	14.5	0.8	clear	9.6	7.5
06/30/02	Polo Grounds	9:15	Clear	15.0	13	0.6	na	9.5	7.5
07/20/02	Aptos Co. Park	9:15	Cloudy	13.5	13.5	0.8	clear	9.6	8
07/20/02	Spreckels Bridge	10:40	Cloudy	13.0	14	0.8	clear	10.6	7.5
05/11/02	Aptos Co. Park	9:31	Clear	12.0	10	0.8	na	8.0	7.5
05/11/02	Spreckels Bridge	na	na	14.0	11???	0.6	clear	8.99/9.27	7.5
07/27/02	Spreckels Bridge	11:20	Foggy	16.0	14	0.8	clear	10.5	7.5
07/27/02	Polo Grounds	10:30	Foggy	14.0	13	0.5	clear	10.0	7.5
08/03/02	Aptos Co. Park	10:00	Cloudy	13.0	15	0.8	clear	9.3	7.5
08/03/02	Spreckels Bridge	11:00	Cloudy	16.5	15	0.7	clear	9.0	7.5
08/17/02	Steel Bridge	11:55	Cloudy/breezy	15.0	14	1.2	clear	9.7	8
08/18/02	Aptos Co. Park	12:35	Cloudy	17.0	14	0.8	clear	9.4	8
08/24/02	Spreckels Bridge	12:25	Clear	17.0	14	0.6	clear	9.9	7.5
08/24/02	Polo Grounds	11:15	Foggy	14.0	12.5	0.5	clear	9.4	7.5
09/14/02	Steel Bridge	9:50	Clear	13.0	12	0.6	clear	8.1	8
09/14/02	Aptos Co. Park	10:20	Clear/foggy	14.0	13.5	0.6	clear	8.7	7.5
09/21/02	Steel Bridge	9:20	Clear	12.0	12	na	clear	9.1	7.5
09/21/02	Aptos Co. Park	10:35	Clear	13.5	13	na	na	9.1	7
09/29/02	Valencia School	9:30	Clear	11.0	10	0.6	clear	10.7	7
09/29/02	Spreckels Bridge	10:15	Clear	14.5	12	0.8	clear	9.1	7.5

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APPENDIX A: FLOW DURATION CURVES

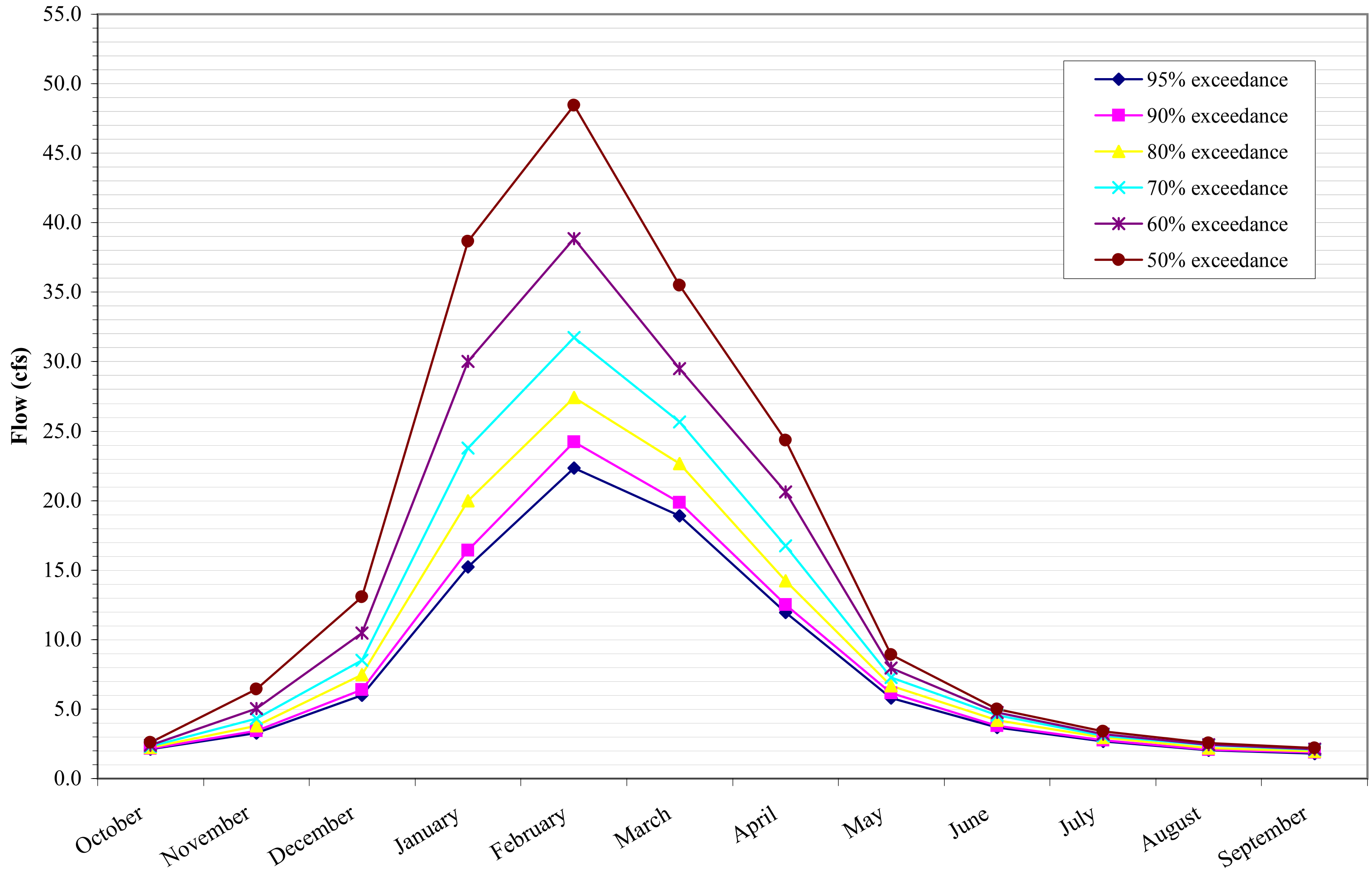

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Figure A-1: Monthly exceedence probabilities in a *wet* year for USGS gages 11159690, Aptos Creek near Aptos, CA (1971 1985) and 11159700, Aptos Creek at Aptos (1958-1971). Exceedence probabilities are calculated by sorting all available mean daily flow values by month. Exceedence probabilities give information about how often a certain flow value is exceeded.

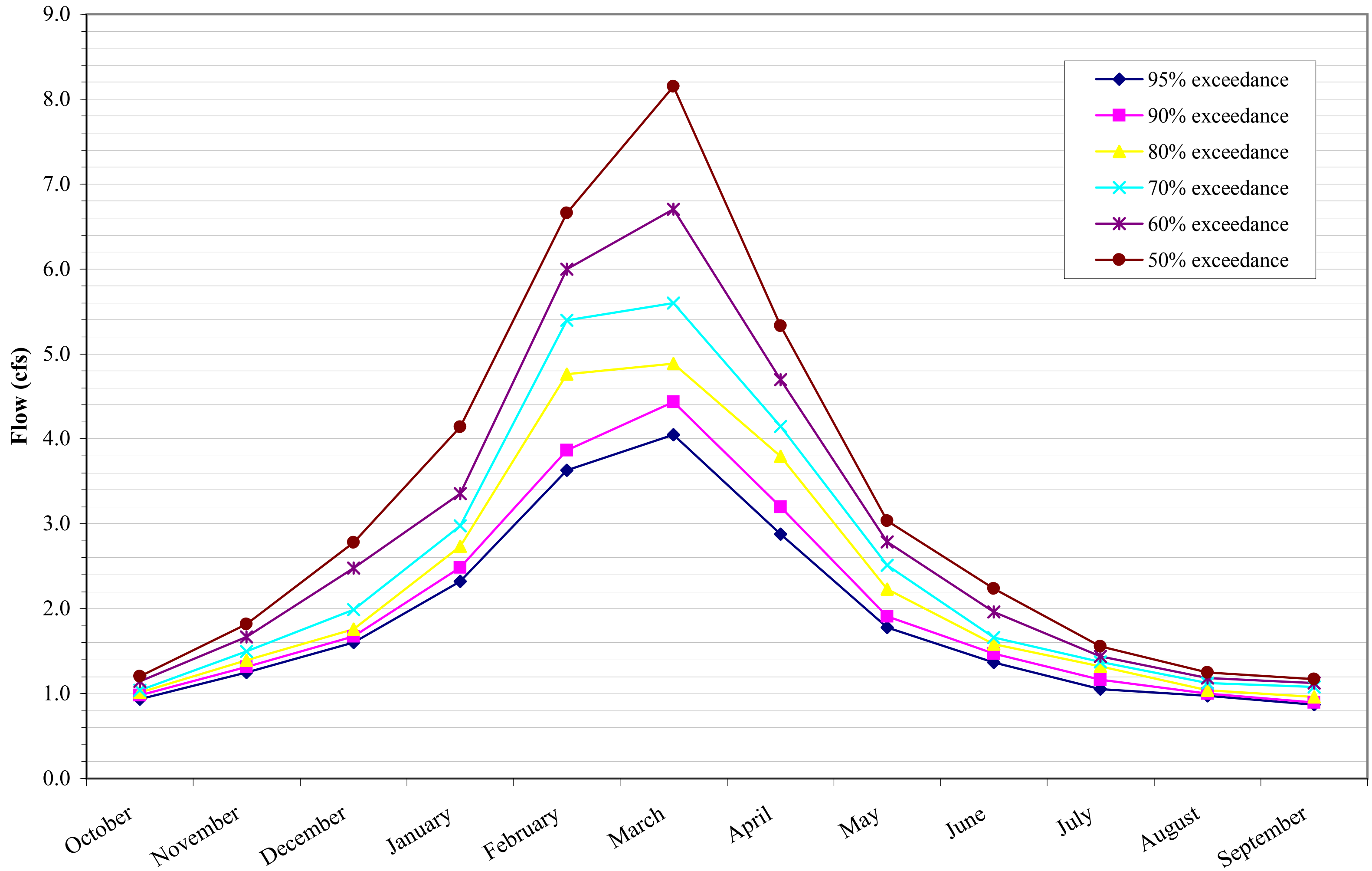

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Figure A-2: Monthly exceedence probabilities in an *average* year for USGS gages 11159690, Aptos Creek near Aptos, CA (1971-1985) and 11159700, Aptos Creek at Aptos (1958-1971). Exceedence probabilities are calculated by sorting all available mean daily flow values by month. Exceedence probabilities give information about how often a certain flow value is exceeded.

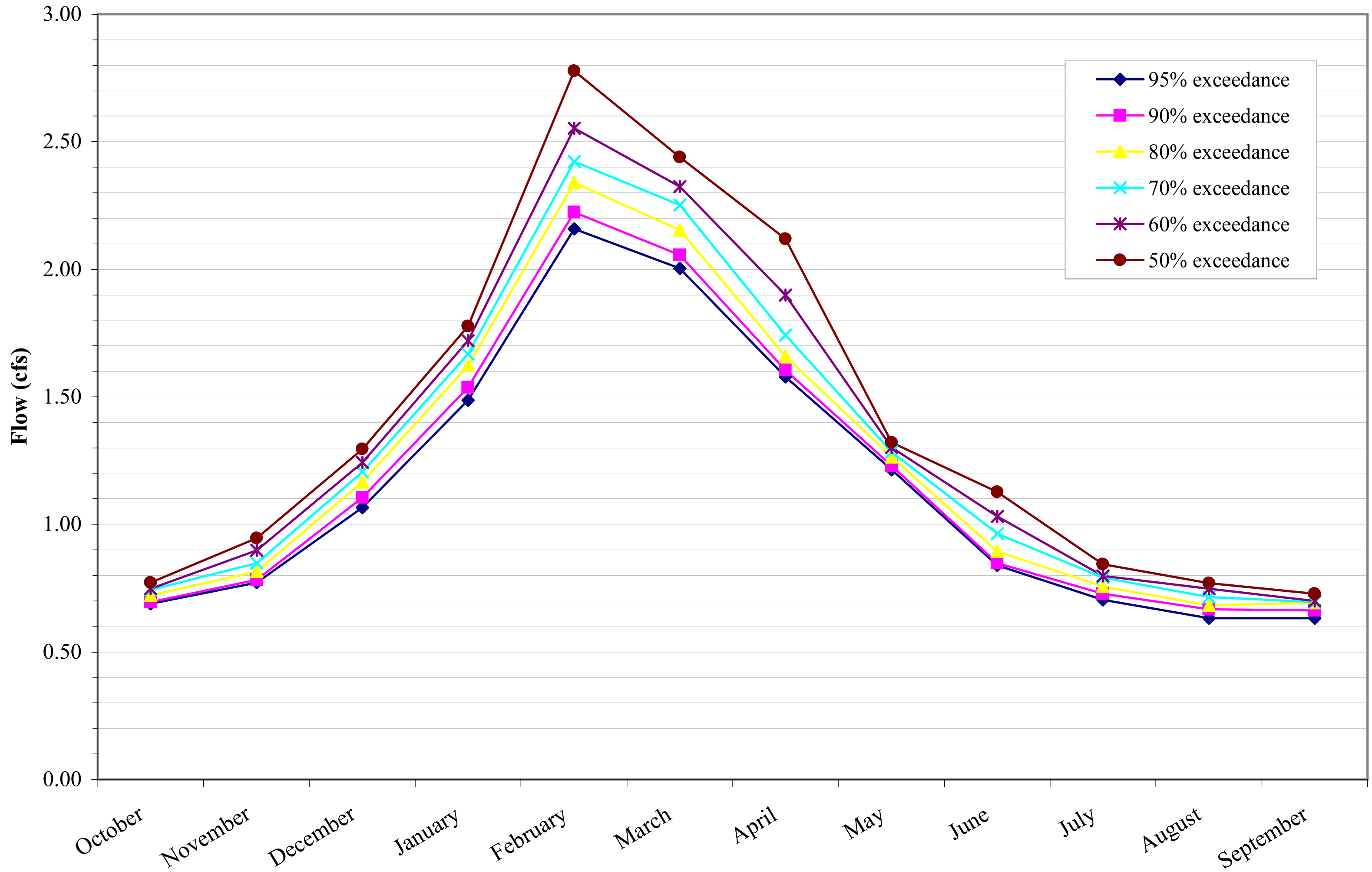

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Figure A-3: Monthly exceedence probabilities in a *dry* year for USGS gages 11159690, Aptos Creek near Aptos, CA (1971-1985) and 11159700, Aptos Creek at Aptos (1958-1971). Exceedence probabilities are calculated by sorting all available mean daily flow values by month. Exceedence probabilities give information about how often a certain flow value is exceeded.

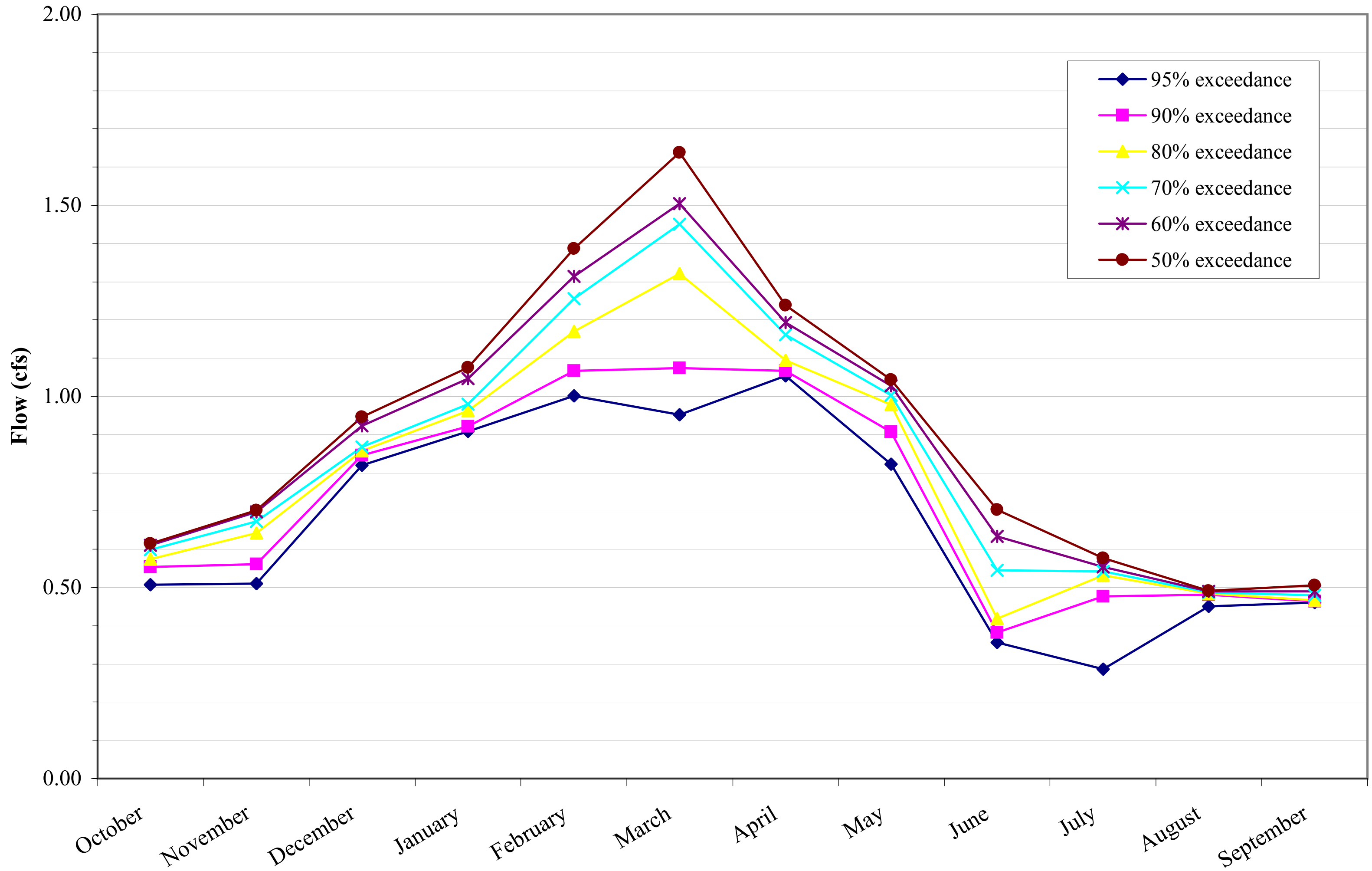

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Figure A-4: Monthly exceedence probabilities in a *drought* year for USGS gages 11159690, Aptos Creek near Aptos, CA (1971-1985) and 11159700, Aptos Creek at Aptos (1958-1971). Exceedence probabilities are calculated by sorting all available mean daily flow values by month. Exceedence probabilities give information about how often a certain flow value is exceeded.

APPENDIX B: STREAM FLOW DATA CONDUCTED BY SH&G AND CWC FOR THE APTOS CREEK WATERSHED ASSESSMENT

Table B: Stream discharge measurements collected by SH&G and CWC in the Aptos Creek Watershed, sorted by location. Those measurements in *italics* were calculated using surface velocities of objects (sticks, leaves) in channel. All other measurements followed standard USGS methods.

	Site	Date	Flow (cfs)	Measured by
Aptos Creek Tributary	Steel Bridge	9/11/01	1.16	SHG
	Steel Bridge	9/22/01	1.20	CWC
	Steel Bridge	10/6/01	1.40	CWC
	Steel Bridge	10/27/01	1.30	CWC
	Steel Bridge	11/10/01	1.30	CWC
	Steel Bridge	11/29/01	*10.5*	SHG
	Steel Bridge	12/1/01	3.62	CWC
	Steel Bridge	1/2/02	4.05	CWC
	Steel Bridge	1/5/02	18.5	CWC
	Steel Bridge	1/12/02	7.37	CWC
	Steel Bridge	3/1/02	4.58	CWC
	Steel Bridge	3/29/02	7.21	CWC
	Steel Bridge	5/1/02	3.56	CWC
	Steel Bridge	6/1/02	3.21	CWC
	Steel Bridge	6/22/02	2.49	CWC
	Steel Bridge	8/17/02	1.86	CWC
	Steel Bridge	9/21/02	0.53	CWC
	County Park	9/11/01	1.36	SHG
	County Park	9/26/01	1.32	SHG/CWC
	County Park	10/6/01	1.28	CWC
	County Park	10/27/01	1.15	CWC
	County Park	11/10/01	1.44	CWC
	County Park	11/27/01	1.79	SHG
	County Park	12/17/01	*18.4*	SHG
	County Park	1/5/02	6.83	CWC
	County Park	1/12/02	9.70	CWC
	County Park	1/17/02	8.30	SHG
	County Park	2/2/02	3.01	CWC
	County Park	3/1/02	4.74	CWC
	County Park	3/29/02	10.15	CWC
	County Park	5/1/02	3.72	CWC
	County Park	6/1/02	1.07	CWC
	County Park	6/22/02	2.49	CWC
	County Park	7/20/02	1.76	CWC
	County Park	8/3/02	1.65	CWC
	County Park	8/18/02	1.33	CWC
	County Park	9/21/02	0.66	CWC

	Site	Date	Flow (cfs)	Measured by
Valencia Creek Tributary	Polo Fields	11/29/01	*5.65*	SHG
	Polo Fields	12/8/01	2.09	CWC
	Polo Fields	1/19/02	2.22	CWC
	Polo Fields	2/16/02	7.80	CWC
	Polo Fields	3/9/02	2.19	CWC
	Polo Fields	3/16/02	1.45	CWC
	Polo Fields	4/6/02	1.30	CWC
	Polo Fields	5/4/02	0.32	CWC
	Polo Fields	6/8/02	0.76	CWC
	Polo Fields	6/30/02	0.27	CWC
	Polo Fields	7/27/02	0.15	CWC
	Polo Fields	8/24/02	0.42	CWC
	Valencia School	11/12/01	20.9	SHG
	Valencia School	12/1/01	0.52	CWC
	Valencia School	12/8/01	1.66	CWC
	Valencia School	12/15/01	1.62	CWC
	Valencia School	12/17/01	*20.9*	SHG
	Valencia School	1/17/02	1.75	SHG
	Valencia School	1/19/02	1.50	CWC
	Valencia School	2/16/02	0.91	CWC
	Valencia School	3/9/02	1.19	CWC
	Valencia School	3/16/02	1.04	CWC
	Valencia School	4/6/02	0.82	CWC
	Trout Gulch	11/29/01	*7.34*	SHG
	Trout Gulch	12/17/01	*4.00*	SHG
	Trout Gulch	1/17/02	*0.88*	SHG
mainstem Aptos Creek	Spreckels	11/12/01	16.7	SHG
	Spreckels	11/27/01	3.26	SHG
	Spreckels	12/15/01	4.01	CWC
	Spreckels	1/17/02	8.50	SHG
	Spreckels	1/31/2002	3.49	CWC
	Spreckels	3/21/02	5.33	CWC
	Spreckels	5/11/02	3.39	CWC
	Spreckels	6/30/02	1.02	CWC
	Spreckels	7/20/02	1.17	CWC
	Spreckels	7/27/02	0.72	CWC
	Spreckels	8/3/02	0.98	CWC
	Spreckels	8/24/02	0.24	CWC
	Spreckels	9/21/02	0.59	CWC